The Journal of Bone and Joint Surgery

The Official Publication of
The American Orthopaedic Association
The British Orthopaedic Association
The American Academy of Orthopaedic Surgeons
The Australian Orthopaedic Association
The Canadian Orthopaedic Association
American Society for Surgery of the Hand
New Zealand Orthopaedic Association
South African Orthopaedic Association

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American Volume

TABLE OF CONTENTS

October 1958

PAGE

Reversibility of Pregangrene in the Severely Ischaemic Limb.
By *A. W. Humphries, M.D.*, *V. G. deWolfe, M.D.*, and *F. A. LeFevre, M.D.*, Cleveland, Ohio 983

Selected Aspects of Acute and Chronic Gouty Arthritis. An Internist's Interpretation of an Orthopaedist's Experiences with Gout and Gouty Arthritis.
By *John H. Talbott, M.D.*, Buffalo, New York 994

Use of Cutis as an Interposing Membrane in Arthroplasty of the Knee.
By *Joseph E. Brown, M.D.*, *W. H. McGaw, M.D.*, and *Darrell T. Shaw, M.D.*, Cleveland, Ohio 1003

Gastrocnemius Recession. Five-Year Report of Cases.
By *Luther M. Strayer, Jr., M.D.*, Bridgeport, Connecticut 1019

Management of Brachial-Plexus Injuries (Traction Type).
By *Major John F. Tracey*, and *Lieutenant Colonel Earl W. Brannon*, Medical Corps, United States Air Force 1031

Observations of Neuropathic (Charcot) Joints Occurring in Diabetes Mellitus.
By *Julian E. Jacobs, M.D.*, Charlotte, North Carolina 1043

A Comparison of Foot Forms Among the Non-Shoe and Shoe-Wearing Chinese Population.
By *Lam Sim-Fook, M.B., B.S.*, and *A. R. Hodgson, M.B., Ch.B., F.R.C.S.*, Hong Kong 1058

de Quervain's Disease. A Clinical and Anatomical Study.
By *Luiz Leão, M.D.*, Rio de Janeiro, Brazil 1063

Tendon Transfers to Restore Function of Hands in Tetraplegia, Especially After Fracture-Dislocation of the Sixth Cervical Vertebra on the Seventh.
By *Paul R. Lipscomb, M.D.*, *Earl C. Elkins, M.D.*, and *Edward D. Henderson, M.D.*, Rochester, Minnesota 1071

Histochemical Studies on Glycogen in Normal Ossification and Calcification.
By *Fritz Schajowicz, M.D.*, and *Rómulo L. Cabrini, M.D.*, Buenos Aires, Argentina... 1081

Fracture Healing in Rats Treated with Aminoacetonitrile.
By *Ignacio V. Ponseti, M.D.*, and *Fernando Aleu, M.D.*, Iowa City, Iowa 1093

The Effect of Pressor and Depressor Drugs on Intramedullary Bone-Marrow Pressure.
By *Arthur H. Stein, Jr., M.D.*, *Harry C. Morgan, M.D.*, and *Roberto F. Porras, M.D.*, St. Louis, Missouri 1103

Minerals, Collagen, and Hexosamine in Rat Femora.
By *Harry Sobel, Ph.D.*, Los Angeles, California 1111

The Extra-osseous and Intra-osseous Blood Supply of the Talus.
By *Robert A. Haliburton, M.D.*, *C. Roger Sullivan, M.D.*, *Patrick J. Kelly, M.D.*, and *Lowell F. A. Peterson, M.D.*, Rochester, Minnesota 1115

(Continued on page 3)

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TABLE OF CONTENTS

(Continued from page 1)

PAGE

Sequelae of Experimental Dislocation of a Weight-Bearing Ball-and-Socket Joint in a Young Growing Animal. Gross Alterations in Bone and Cartilage.
By *William S. Smith, M.D., Richard J. Ireton, M.D.,* and *Carl R. Coleman, M.D.,* Columbus, Ohio 1121
Recurrent Locking of an Index Finger.
By *Adrian E. Flatt, M.D., F.R.C.S.,* Iowa City, Iowa 1128
Malignant Giant-Cell Tumor of the Ulna. Report of a Case of Eighteen Years' Duration.
By *Robert M. Kimball, M.D.,* and *Dominic A. DeSanto, M.D.,* San Diego, California 1131
Chondrosarcoma of the Small Bones of the Hand.
By *W. Edward Lansche, M.D.,* and *Harland J. Spjut, M.D.,* St. Louis, Missouri 1139
Bilateral Recurrent Dislocations of the Superior Tibiofibular Joint with Peroneal-Nerve Palsy. A Case Summary.
By *Captain Joel B. Dennis,* and *Lieutenant Colonel Ben A. Rutledge,* Medical Corps, United States Army 1146
Recurrent Calcified Leiomyoma of the Pelvis and Gluteal Regions Complicated by Pregnancy. A Case Report.
By *Bernard Cooperman, M.D., Ferdinand F. McAllister, M.D.,* and *Frederick M. Smith, M.D.,* New York, N. Y. 1149
A Goniometer Designed for the Hand.
By *Lieutenant Commander H. Rolf Noer,* Medical Corps, United States Navy, and *Donald R. Pratt, M.D.,* San Francisco, California 1154
Anteroposterior Projection of the Carpometacarpal Joint of the Thumb by Radial Shift of the Carpal Tunnel View.
By *Michael Burman, M.D.,* New York, N. Y. 1156
Anterior-Angled Plates for High Femoral Osteotomies.
By *Patrick G. Laing, M.D., F.R.C.S.,* Pittsburgh, Pennsylvania 1158
A Follow-up Study of the Initial Group of Cases of Skeletal Tuberculosis Treated with Streptomycin, 1946-1948. The United States Veterans Administration and Armed Forces Cooperative Studies of Tuberculosis.
By *Abraham Falk, M.D.,* St. Paul, Minnesota 1161
A Review and Analysis of 11,000 Fractures Seen in a Private Practice of Orthopaedic Surgery, 1937-1956.
By *John E. Emmett, M.D.,* and *Louis W. Breck, M.D.,* El Paso, Texas 1169
The Boston Orthopedic Institution.
By *Jonathan Cohen, M.D.,* Boston, Massachusetts 1176
Proceedings:
Joint Meeting of the American, the British, the Canadian, the Australian, and the South African Orthopaedic Associations 1179
The Orthopaedic Research Society 1196
American Academy for Cerebral Palsy 1203
Robert A. Knight 1207
I. William Nachlas 1208
Henry Franz Ullrich 1210
News Notes 1211
Book Reviews 1214
List of Advertisers ..... Adv. 66
Addresses of Contributors ..... Cover III

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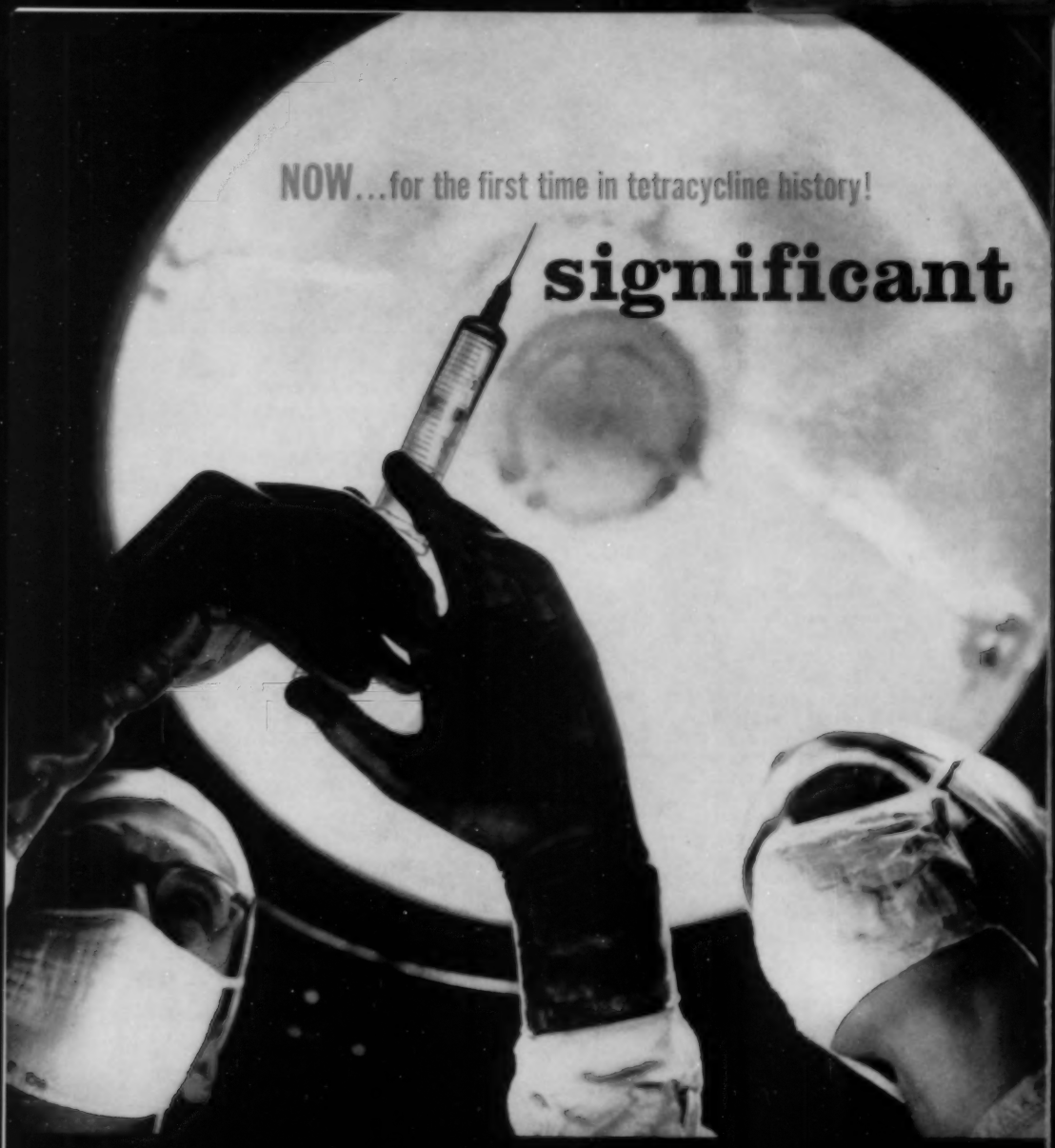

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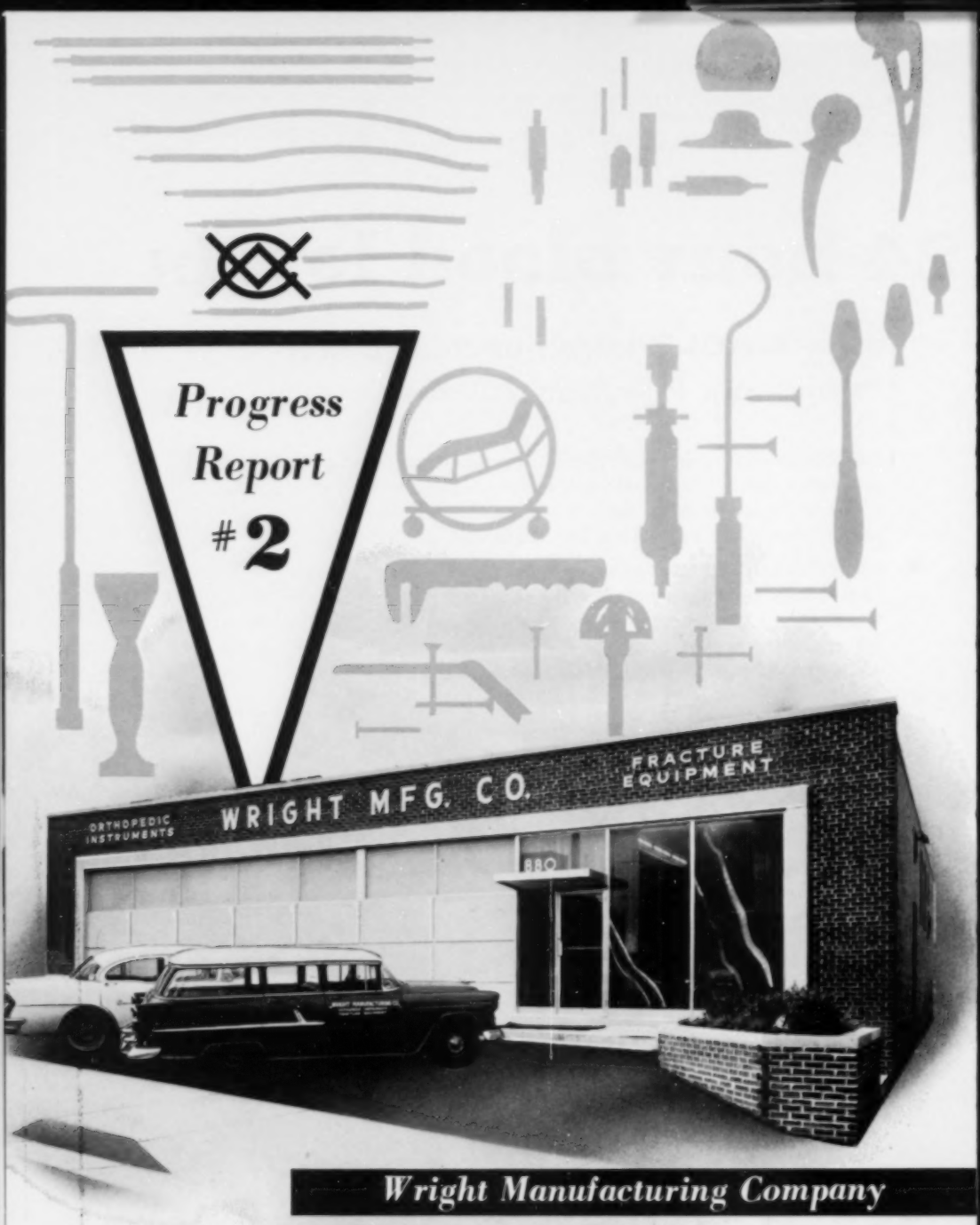

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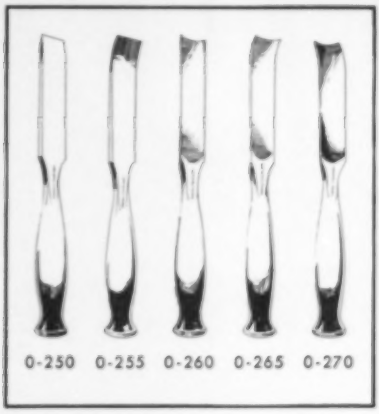

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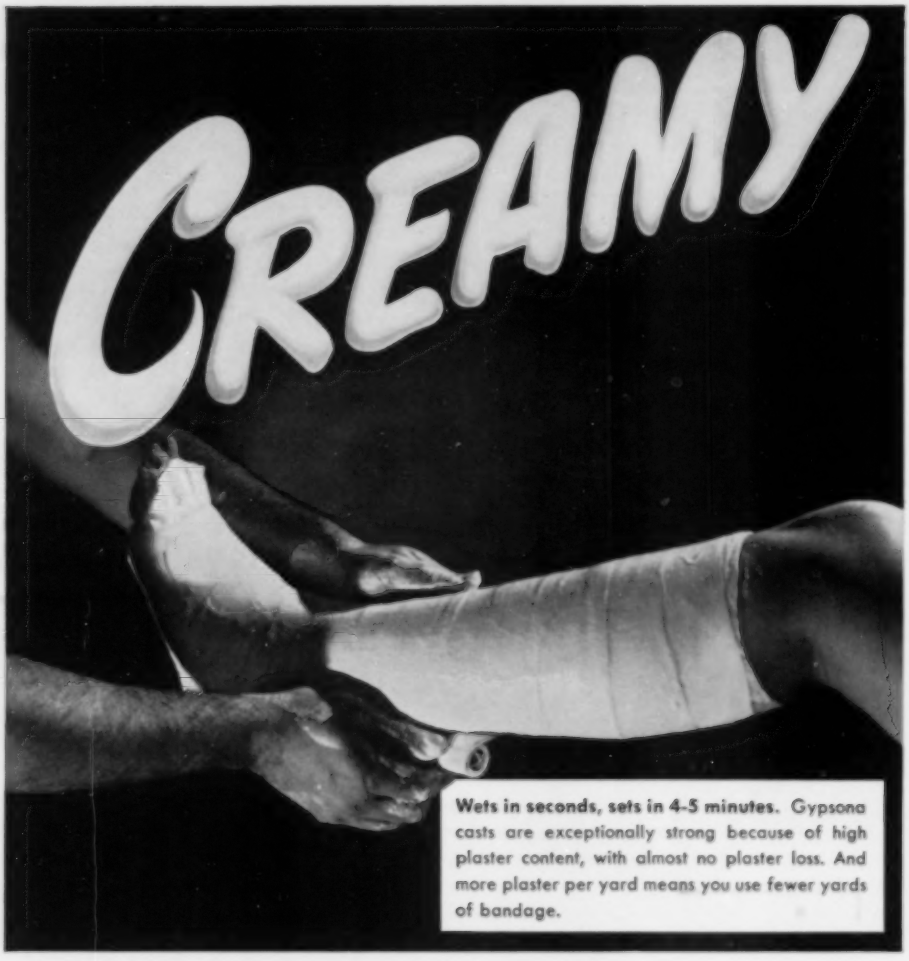
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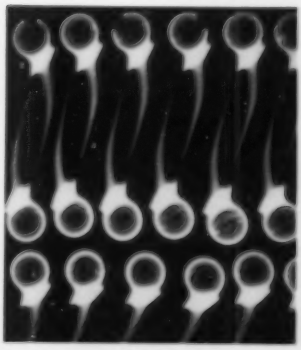

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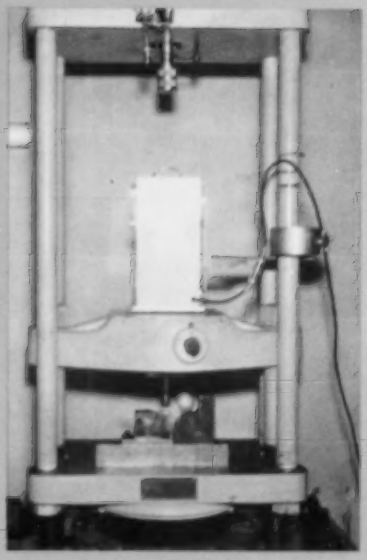

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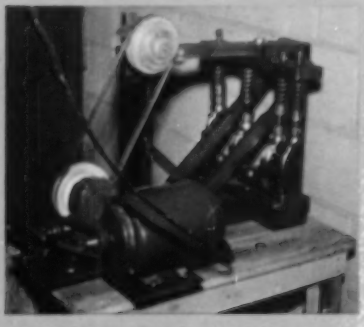

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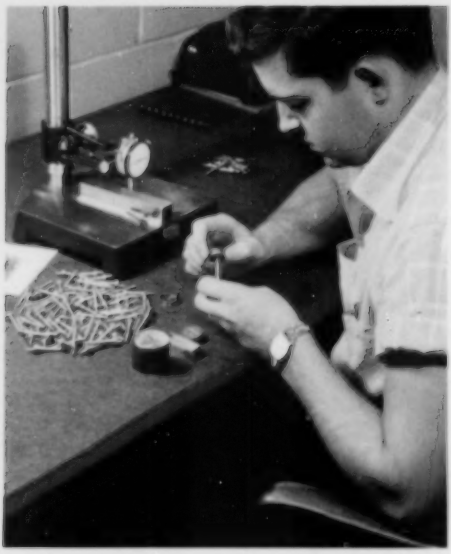

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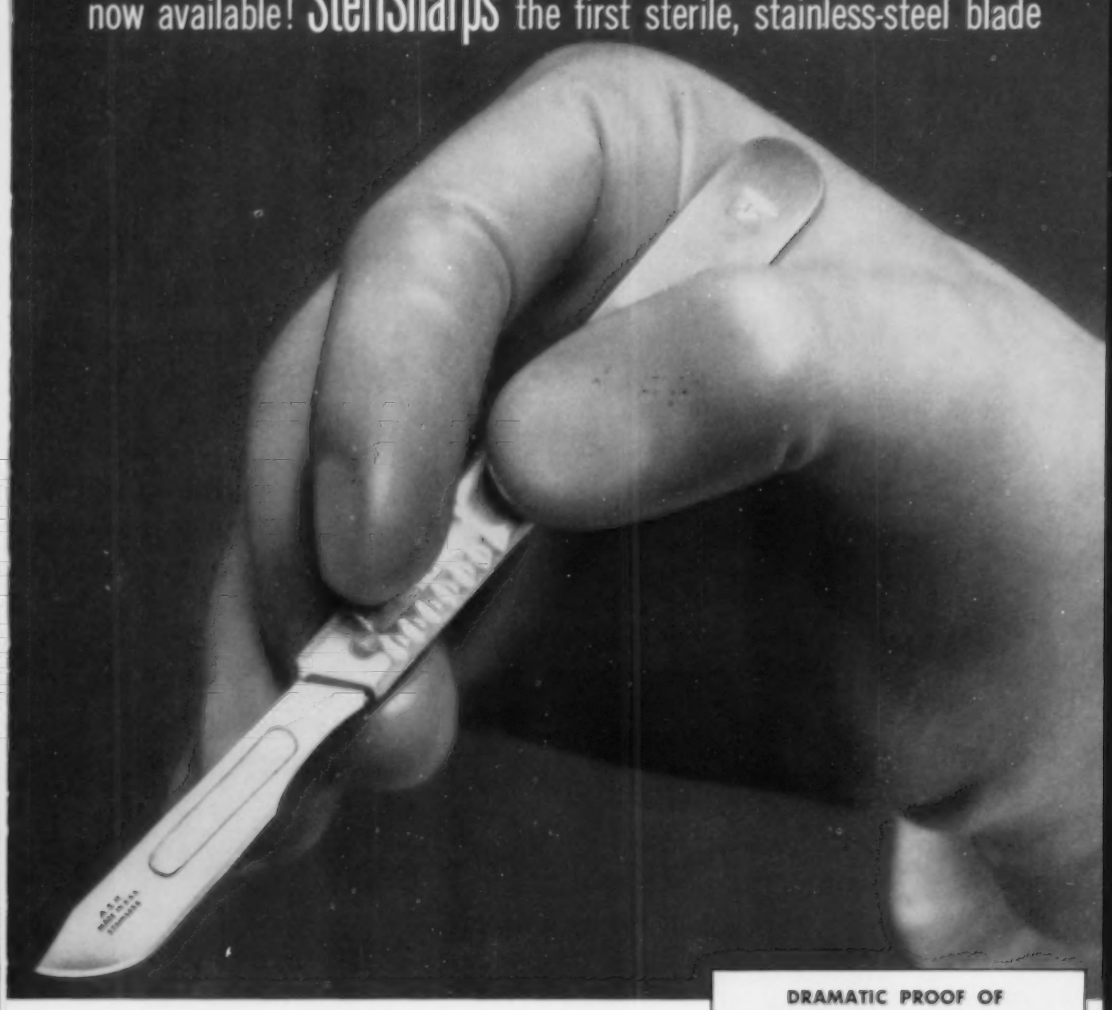

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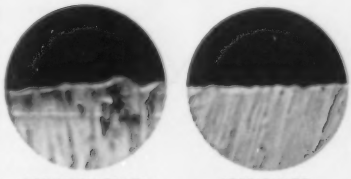


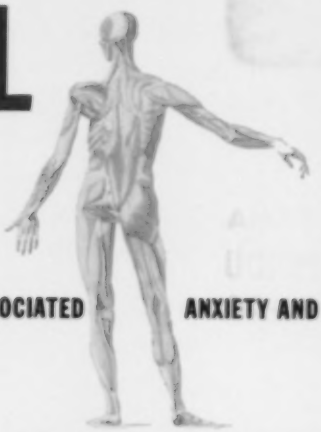
ORDINARY BLADE STERISHARP

These unretouched photos (magnified 1,000 times) show that you can sometimes get a dull carbon blade...demonstrate the superiority of new SteriSharps. The ordinary blade edge (left) is ragged . . . has nicks and burrs that can snag tissue. The SteriSharp (right) has a clean, uniform edge.

A·S·R precision products

SteriSharps... the first and only sterile, stainless-steel surgical blade

UNEXCELLED FOR RELIEF OF SKELETAL MUSCLE SPASM AND ASSOCIATED ANXIETY AND TENSION



Miltown®

meprobamate (Wallace)

Simultaneous relief of muscular tension and anxiety with Miltown improves therapeutic results

The dual action of Miltown in neuromuscular disorders "calms patients made chronically irritable by pain, thereby both improving their mental state and increasing their physical comfort . . . It was found to be the best muscle relaxant available to date for use in these conditions."*

Miltown is notably safe. It does not disturb autonomic balance, and does not impair mental efficiency or physical performance.

*Eisenberg, S. H. and Neviaser, J. S.: The use of meprobamate in the treatment of skeletal muscle spasm. Ann. New York Acad. Sc. **67**:853, May 9, 1957.

EFFECTIVE IN

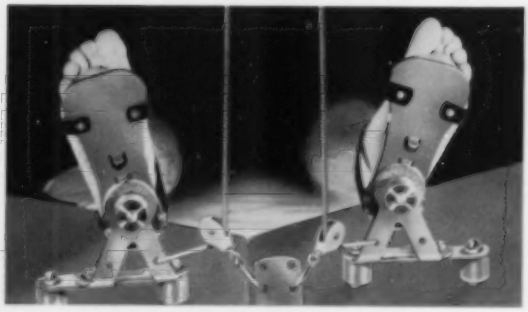
LOW BACK PAIN
FIBROSITIS
TORTICOLLIS
MUSCLE STRAINS
MYOSITIS
LEG CRAMPS
OF PREGNANCY
RHEUMATIC CONDITIONS
TENSION HEADACHES
CEREBRAL PALSY

Supplied: *400 mg. scored tablets, 200 mg. sugar-coated tablets.*

® WALLACE LABORATORIES, *New Brunswick, N. J.*

CM-7299

BOWEN FRACTURE APPLIANCES — GREAT AIDS TO BETTER SURGERY



LEG EXERCISER SETS

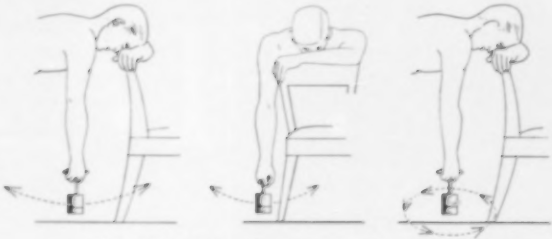
Designed to assist in passive abduction after cup arthroplasty, rehabilitation of paraplegics, and many other cases requiring weight controlled exercises.

- **Rigid Construction—Relatively Light in Weight**
- **Moves Freely on Ball Bearings in All Directions**
- **Protractor Adjustment for Foot Angle Control**
- **Weight Attaching Eyes at Different Levels**
- **Foot and Heel of Exerciser Covered with Foam Rubber**
- **Exercising Board 14" x 48", Hinged at Center and Angled to Approximate the Arc Scribed by the Legs**

ORMANDY PENDULUM EXERCISER

To Prevent Frozen Shoulder

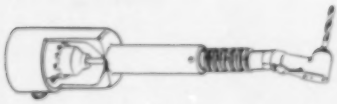
An excellent means to RELIEVE MUSCLE SPASM and PAIN of the shoulder girdle by traction in order to increase the ARC OF MOTION of the scapulo-humeral joint.



Efficient Method of Exercising for Shoulder—Joint Injuries

To Prevent Frozen Shoulder

The compact size of the Pendulum Exerciser will make it possible to increase the arc of motion without hitting the leg of the patient.



ANGLE DRILL ATTACHMENT

For Luck Bone Saw and Stryker Drill

Designed Especially for the Bankhart Operation

Excellent for bone surgery at difficult angles and in restricted areas requiring use of drills, curetting burrs, slotting burrs. Rigidly constructed, light in weight. Entire unit may be sterilized. Two 1/32 inch diameter High Speed Drills supplied with each attachment.

Easily attached to Jacobs chuck with key.

A hole in the end of the drill bit is provided so that the suture can be threaded and pulled through with the extraction of the drill.

GONIOMETER — Pocket Size Anodized Aluminum

A Pocket Size instrument with calculation flexibility allowing complete angle determination in degrees.

Produced from aluminum, anodized and dyed black, with white-lead-filled dial and indications permitting full penetration of radiation and screening a permanent secondary shadow of measurement on the film for consultations and computations.

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In answering advertisements, please mention *The Journal of Bone and Joint Surgery*.

A new concept in the orthopedic-type mattress . . .

New BACK CARE mattress by SIMMONS

First and only mattress with a Built-in Bedboard

BACK CARE® with Built-in Bedboard is adapted to the needs of patients with chronic backache due to sleeping surfaces that do not support spinal structures properly.

The Built-in Bedboard is centered in the mattress. There it exerts its corrective action close to the back where support is needed for relief. Firm inner springs above and below the bedboard give maximum sleeping comfort.

New Back Care was developed in consultation with leading orthopedic surgeons. It was recommended by them as an important adjunct to the management of backache.

We believe that you, Doctor, will find Back Care of great benefit to your orthopedic patients—because it combines the desired degree of firmness and comfort.

Here's how Built-in Bedboard and double-coil construction help your back:

1. Resilient coil support adjusts to your body contours—smooth, button-free surface.

2. Built-in Bedboard keeps your spine level and straight. Scientific corrective action up close to your back where you need it.

3. Extra floating spring support. Bedboard floats on extra layer of springs . . . equalizes weight over all coils. Prevents sag.

BACK CARE

PATENT PENDING

WITH BUILT-IN BEDBOARD

by SIMMONS

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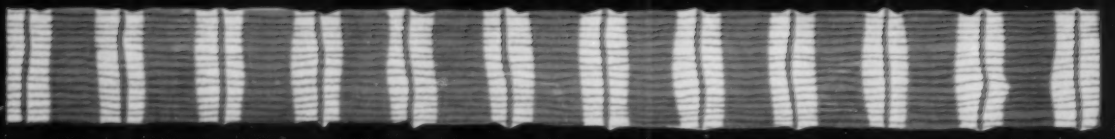
ANNOUNCING two important new Paraflex* products



new

PARAFON*

for relief of pain, stiffness, and disability caused by muscle spasm

new

PARAFON* with PREDNISOLONE

in arthritis

McNEIL

McNEIL LABORATORIES, INC. • PHILADELPHIA 32, PA.

now...the specific muscle relaxant

for relief of the pain–spasm–pain cycle

PARAF

(PARAFLEX Chlorzoxazone† plus TYLENOL® Acetaminophen)

in arthritic and rheumatic disorders

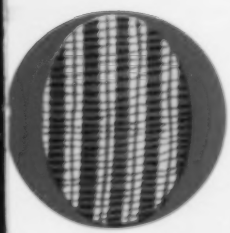
PARAF

with PREDNISO

McNEIL

McNEIL LABORATORIES, INC • PHILADELPHIA 32, PA.

plus the preferred analgesic

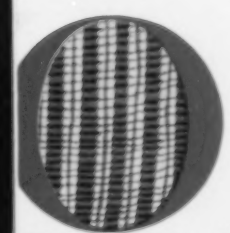


ON*

combines PARAFLEX, the effective low-dosage skeletal muscle relaxant that is specific for painful spasm, and TYLENOL, the preferred analgesic for painful musculoskeletal disorders. Providing benefits that last for up to six hours, PARAFON is effective on the practical dosage of only six tablets daily. Side effects are rare and seldom severe enough to warrant discontinuance of therapy. PARAFON relieves pain and stiffness and helps improve function in acute and chronic low back disorders such as lumbago, acute paravertebral spasm, or sacroiliac strain; osteoarthritis; rheumatoid arthritis; traumatic hydrarthrosis; and traumatic muscle injuries.

supplied: Tablets, scored, pink, bottles of 50. Each tablet contains: PARAFLEX Chlorzoxazone 125 mg.†; and TYLENOL Acetaminophen 300 mg.

†U. S. Patent Pending *Trademark



ON*

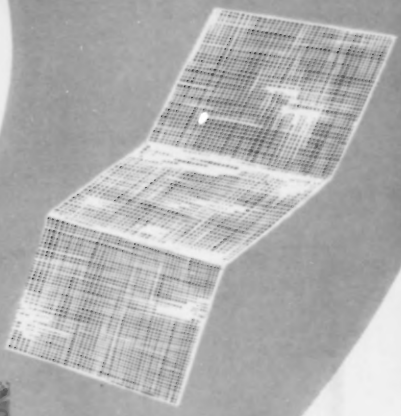
LONE

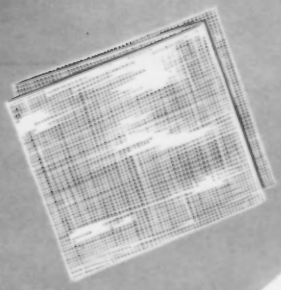
adds the anti-inflammatory action of prednisolone to the relief of pain and spasm achieved with PARAFON. PARAFON WITH PREDNISOLONE is useful in many arthritic and rheumatic disorders, such as rheumatoid arthritis, rheumatism, myositis, neuritis, tenosynovitis, fibrositis, bursitis, spondylitis, and osteoarthritis.

supplied: Tablets, scored, buff colored, bottles of 36. Each tablet contains: PARAFLEX Chlorzoxazone 125 mg., TYLENOL Acetaminophen 300 mg., and prednisolone 1 mg.

21SA33

The NEW DUAL PURPOSE





3″ x 9″ STRIP

Shorter length ends waste on small area wounds. New Z-fold insures perfect graft takes. Guaranteed sterile at time of use.

3″ x 3″ PAD

Three-ply, fine-mesh gauze, lightly impregnated — for use in physician's office, industrial medical department, first aid.

6th SIZE of VASELINE® PETROLATUM GAUZE

Now supplied in:

1/2″x 72″	3″x 18″
1″x 36″	3″x 36″
3″x 3″/ 3″x 9″	6″x 36″

Sole Maker:

CHESEBROUGH-POND'S INC.
Professional Products Division
New York 17, N. Y.

VASELINE *is a registered trademark of Chesebrough-Pond's Inc.*

DePuy

SCUDERI

HIP PROSTHESIS UNITS

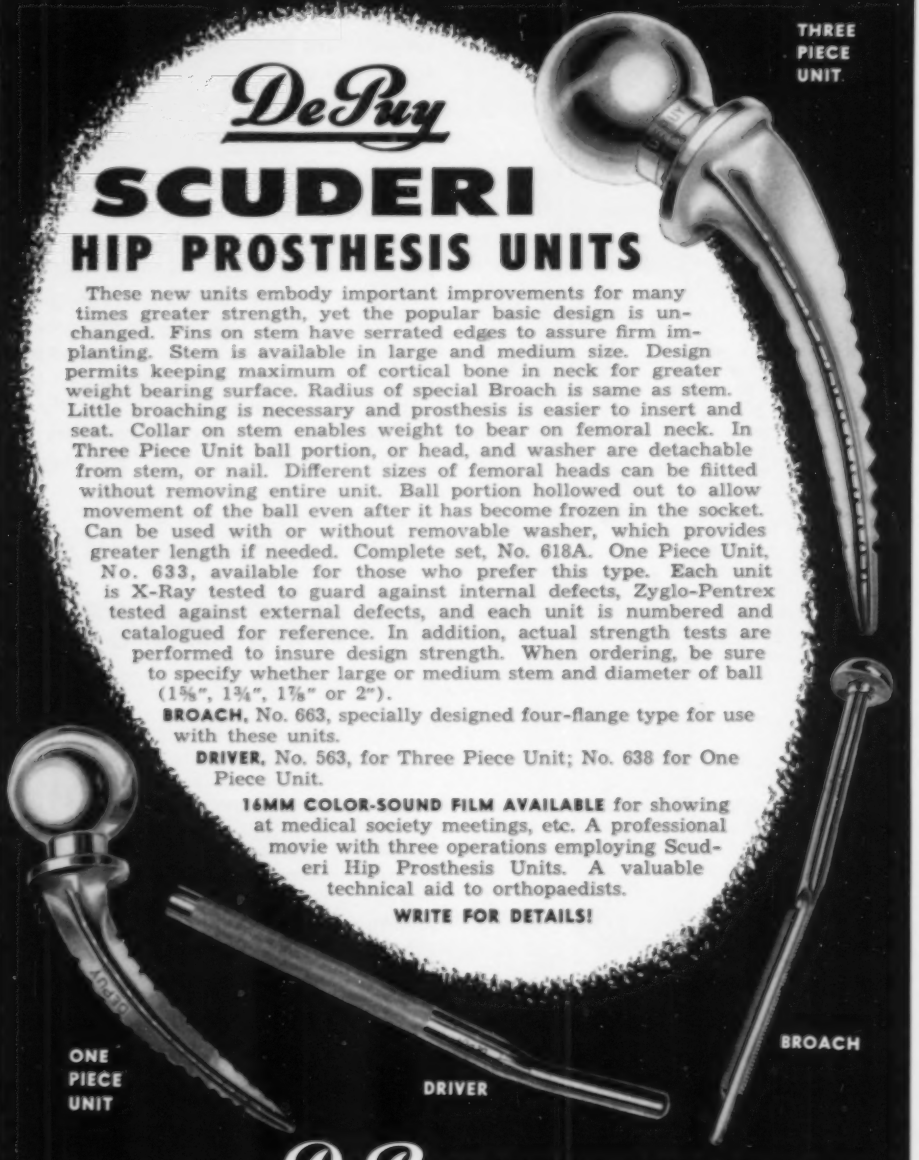
These new units embody important improvements for many times greater strength, yet the popular basic design is unchanged. Fins on stem have serrated edges to assure firm implanting. Stem is available in large and medium size. Design permits keeping maximum of cortical bone in neck for greater weight bearing surface. Radius of special Broach is same as stem. Little broaching is necessary and prosthesis is easier to insert and seat. Collar on stem enables weight to bear on femoral neck. In Three Piece Unit ball portion, or head, and washer are detachable from stem, or nail. Different sizes of femoral heads can be fiitted without removing entire unit. Ball portion hollowed out to allow movement of the ball even after it has become frozen in the socket. Can be used with or without removable washer, which provides greater length if needed. Complete set, No. 618A. One Piece Unit, No. 633, available for those who prefer this type. Each unit is X-Ray tested to guard against internal defects, Zyglo-Pentrex tested against external defects, and each unit is numbered and catalogued for reference. In addition, actual strength tests are performed to insure design strength. When ordering, be sure to specify whether large or medium stem and diameter of ball (1⅝", 1¾", 1⅞" or 2").

BROACH, No. 663, specially designed four-flange type for use with these units.

DRIVER, No. 563, for Three Piece Unit; No. 638 for One Piece Unit.

16MM COLOR-SOUND FILM AVAILABLE for showing at medical society meetings, etc. A professional movie with three operations employing Scuderi Hip Prosthesis Units. A valuable technical aid to orthopaedists.

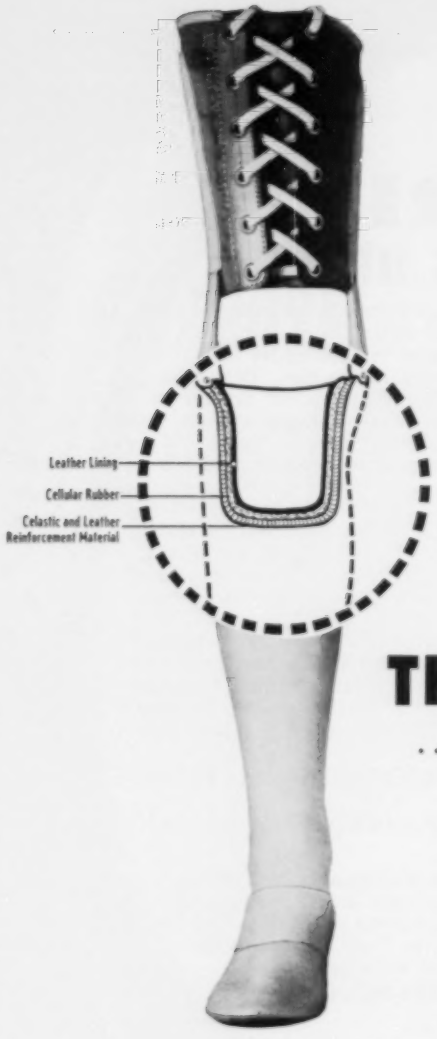
WRITE FOR DETAILS!



DePuy MANUFACTURING CO., INC.

Since 1895 Standard of Quality

WARSAW 8, INDIANA



The Soft Socket for below-knee amputations provides a new solution for sensitive stumps where weight-bearing has been or may be uncomfortable.

In constructing the Soft Socket Limb, a special socket is made which incorporates a layer of a new nitrogen-filled cellular rubber. This produces a slight but tangible degree of softness and resiliency in the socket, with the result that the sudden pressure on the stump caused by the first impact of weight-bearing is greatly reduced. The special characteristics of cellular rubber prevent "packing", even after long periods of use, ensuring that the socket of the prosthesis will retain its original shape.

THE SOFT SOCKET

. . . a new solution for sensitive stumps

Over the years, Hanger has developed, perfected and introduced outstanding achievements in artificial limbs and has cooperated closely with the program of prosthetic research sponsored by the National Academy of Sciences—National Research Council. Hanger continues Research by testing new ideas, methods and materials in constantly seeking the better way to make even better prostheses that will bring greater happiness to amputees.

Hanger PROSTHETIC

AVAILABLE AT AUTHORIZED FACILITIES IN THE FOLLOWING CITIES:

Eastern Region:
BALTIMORE 1, MD.
BOSTON 15, MASS.
CHARLESTON 2, W. VA.
CHARLOTTE 4, N. C.
NEW YORK 11, N. Y.
PHILADELPHIA 7, PA.
RALEIGH, N. C.
RICHMOND 19, VA.
ROANOKE 12, VA.
WASHINGTON 13, D. C.
WILKES-BARRE, PA.

Midwestern Region:
CHICAGO 5, ILL.
CINCINNATI 29, OHIO
DALLAS 1, TEXAS
EVANSVILLE, IND.
FORT WAYNE, IND.
INDIANAPOLIS 2, IND.
OKLAHOMA CITY 3, OKLA.
PEORIA 4, ILL.
ST. LOUIS 3, MO.
WICHITA, KANSAS

Central Region:
COLUMBUS 8, OHIO
PITTSBURGH 1, PA.

Southeastern Region:
ATLANTA 1, GA.
BIRMINGHAM 1, ALA.
COLUMBIA 5, S. C.
JACKSONVILLE, FLA.
KNOXVILLE, TENN.
MIAMI 37, FLA.
MOBILE, ALA.
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NASHVILLE, TENN.
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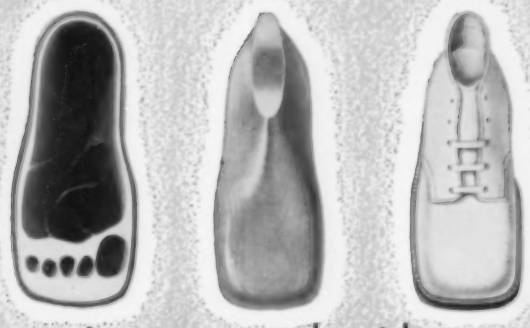
Child Life provides a

TRUE Straight Last Shoe

No Inflare—
No Outflare



to assist your work with young patients

When young feet need the advantages of Straight Last Construction, CHILD LIFE Straight Last Shoes are readily adaptable to your prescription work.

They allow full freedom for normal foot action and growth . . . provide ample toe room for all toes to grow straight forward. Additionally, these special shoes for children are readily adaptable for all prescribed wedges . . . and are good "follow-through" shoes for corrections already attained. Because of their welt construction, they also lend themselves well to use with Denis Browne Splints. And, as you can see, CHILD LIFE Straight Last Shoes are styled in the basic popular patterns.

Write for the names of the competent CHILD LIFE dealers in your area.

HERBST Shoe Manufacturing Co., Milwaukee 45, Wis.

In answering advertisements, please mention *The Journal of Bone and Joint Surgery*.

Supp-hose*†

FOR LEG FATIGUE AND MILD VARICOSITIES

Recent clinical research demonstrated the excellent value of Supp-hose for leg fatigue, and mild disorders where heavy surgical stockings are not prescribed. The advantage of Supp-hose is that it looks just like any sheer nylon stocking, thus it overcomes one of the main objections of the patient concerned about her appearance.

SO MANY WOMEN COMPLAIN ABOUT LEG FATIGUE!

As you know, expectant mothers, housewives, working women, and women with mild varicosities all complain about discomfort of the extremities. Supp-hose eases this leg fatigue and gives gentle support all day long. Yet Supp-hose contains no rubber! Every stitch is fine nylon with a special twist that provides an elastic quality.

A VERY ECONOMICAL STOCKING!

Patented Supp-hose costs a woman just one-third what she usually pays for heavier surgical stockings. And wear tests indicate Supp-hose should give five times the wear of ordinary nylons. Supp-hose is available in proportioned sizes in beige, natural and white. At drug and department stores.

K&R KAYSER-ROTH HOSIERY COMPANY, Inc., 200 Madison Avenue, N. Y. 16, N. Y. Sold in Canada.

PAIN . . .

the first concern
in patient
after patient

pain control without narcotics

Zactirin is a potent analgesic. It controls pain as effectively as does codeine, but its use is free from the well-known liabilities of codeine.

2 Zactirin tablets are equivalent in analgesic potency to ½ grain of codeine plus 10 grains of acetylsalicylic acid.

Zactirin is non-narcotic.

Zactirin is effectively anti-inflammatory.

Wyeth
Philadelphia 1, Pa

Zactirin®

Ethoheptazine Citrate with Acetylsalicylic Acid

Supplied in distinctive, 2-layer yellow-and-green tablets, bottles of 48. Each tablet contains 75 mg. of ethoheptazine citrate and 325 mg. (5 grains) of acetylsalicylic acid.

A totally new concept in patient handling

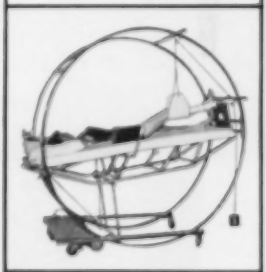
Introducing

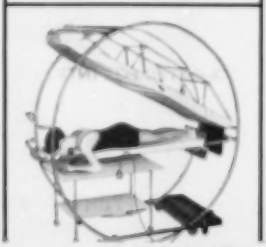
Stryker Circ-O-lectric

The new Circ-O-lectric Universal Hospital Bed is the first economical all-purpose unit developed for the comfort of the patient and for the convenience of the nurse.

Circ-O-lectric Bed advantages are many and varied . . . whenever special position is required and wherever patient handling is necessary. It features patient operated 180° electrical turning and 90° tilting with manual gatching. The bed can not only be used by the general surgeon and the orthopedic surgeon, but by many other specialists as well.

For additional information write, or call today.





Stryker Manufacturing Quality Medical Equipment for 15 years

Orthopedic Frame Company

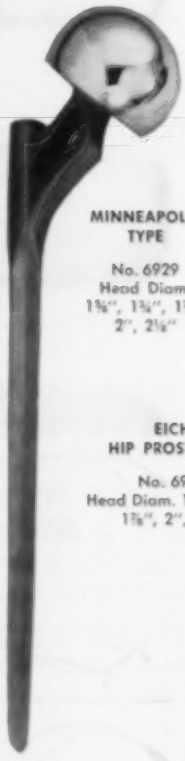
420 ALCOTT STREET • KALAMAZOO, MICHIGAN

HIP PROSTHESES

IN A CHOICE OF DESIGNS AND A VARIETY OF SIZES

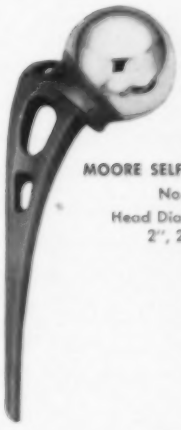
IN VITALLIUM . . .

THE ONLY ALLOY CREATED SPECIFICALLY FOR SURGICAL USE



MINNEAPOLIS TYPE

No. 6929
Head Diam.
1⅝", 1¾", 1⅞"
2", 2⅛"



MOORE SELF-LOCKING HIP PROSTHESIS

No. 6939 Regular
Head Diam. 1½", 1⅝", 1¾", 1⅞",
2", 2⅛", 2⅜", 2¼", 2½"

MODIFIED MOORE HIP PROSTHESIS

No. 6939-1 Narrow stem
Head Diam. 1⅝", 1¾", 1⅞"

EICHER HIP PROSTHESIS

No. 6927
Head Diam. 1⅝", 1¾",
1⅞", 2", 2⅛"

F. R. THOMPSON HIP PROSTHESIS

No. 6936-1	Straight	1⅝" Head Diam.
6936-2	Straight	1¾" Head Diam.
6936-3	Left	1¾" Head Diam.
6936-4	Right	1¾" Head Diam.
6936-5	Straight	1⅞" Head Diam.
6936-6	Left	1⅞" Head Diam.
6936-7	Right	1⅞" Head Diam.
6936-8	Straight	2" Head Diam.
6936-9	Straight	2⅛" Head Diam.

X-RAYED FOR INTERNAL SOUNDNESS

SURFACE INSPECTED BY ZYGLO†

AUSTENAL, INC. *Surgical* DIVISION

224 EAST 39TH STREET · NEW YORK 16, N. Y.

® by Austenal, Inc.

Printed in U.S.A.

†Trade Mark Magnaflux Corp.

VITALLIUM® HIP PROSTHESES IN THOUSANDS OF CASES PROVED SUCCESSFUL

Roentgenogram of a bilateral arthroplasty utilizing Vitallium Moore prostheses.

Moore's observation is one of many recent statements concerning treatment of the so-called "unsolvable fracture." Once considered the plague of the elderly, fractures of the hip can now be treated with less risk and shock than was believed possible just a few years ago.

"The indications for the use of prostheses appear to be becoming more clearly defined. Non-union, arthritis, and asceptic necrosis are almost universally accepted as indications, while the use of prostheses in fresh fractures of the femoral neck at any age, but in the aged particularly, is increasing."[2] "Use of the femoral-head prosthesis in fresh fractures, when indicated, may reduce the incidence of uraemia, hypostatic pneumonia and death."[3]

"The advantages claimed for this method are early ambulation, reduced hospitalization or periods in convalescent homes, facilitation of nursing care, the avoidance of secondary operations, and a reduction in cost to the patient."[3]. Surgical complications have been minimal and morbidity and mortality are comparable to that of simple Smith-Petersen nailing. The disappointments of asceptic necrosis and mechanical failure that accompany the latter procedure have been avoided."[4]

Every Vitallium hip prosthesis is made with exacting care and precision. From selection of the virgin metals to the finished product, Austenal's quality control procedures assure you of the very best prosthesis worthy of permanent implantation.
"Vitallium was selected as the metal of choice because of its long-proved ability to remain absolutely unchanged within the body. The assurance is lacking in steel, acrylics, and in nylon."[5] "Apparently Vitallium is inert in the tissues, and it is possible that the prosthesis may last indefinitely."[1]

INDICATED USES FOR HIP PROSTHESES ACCORDING TO PROFESSIONAL REPORTS

- Acute Unstable Fractures (Pauwels' Cl. III)[1, 3, 4, 5]
- Acute Fractures in the Aged[2, 3, 4, 7, 8]
- Ununited Fractures (Long-Term)[1, 5, 6, 9]
- Delayed Non-Union[2, 6]
- Pathological Fractures[1, 2, 4, 5, 7]
- Asceptic Necrosis[1, 2, 6, 7, 9]
- Avascular Necrosis[5]
- Osteoarthritis[1, 2, 5, 6, 9, 10]
- Bilateral Ankylosis[10]
- Salvage[6, 7, 9]

REFERENCES:

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Doshay, L.J., and Constable, K.: Treatment of Paralysis Agitans with Orphenadrine (Disipal) Hydrochloride: Results in One Hundred Seventy-Six Cases, J.A.M.A. *163*:1352 (Apr. 13) 1957.

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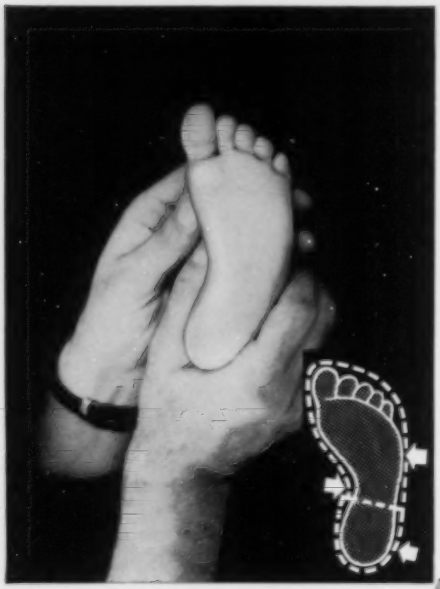

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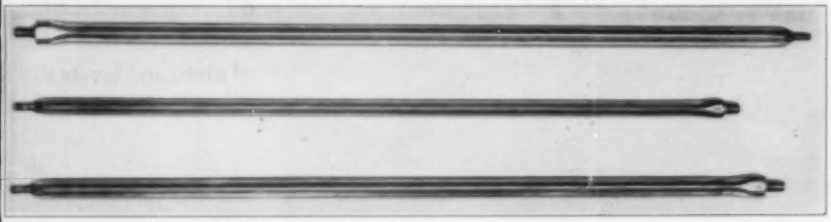

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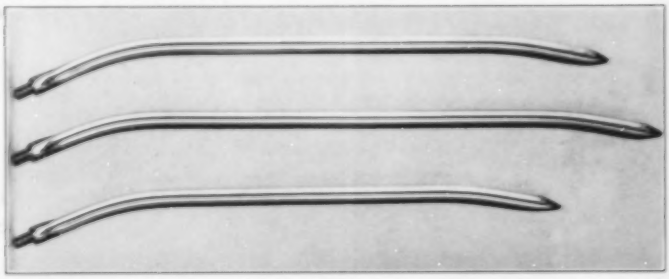

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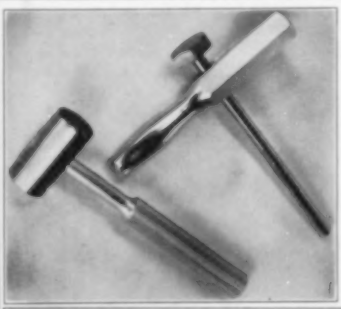

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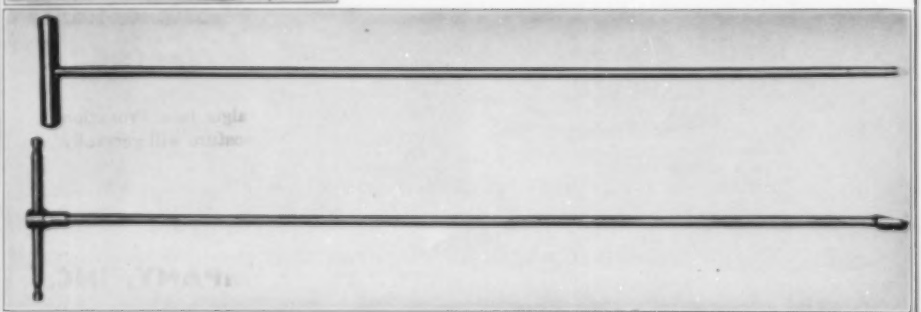

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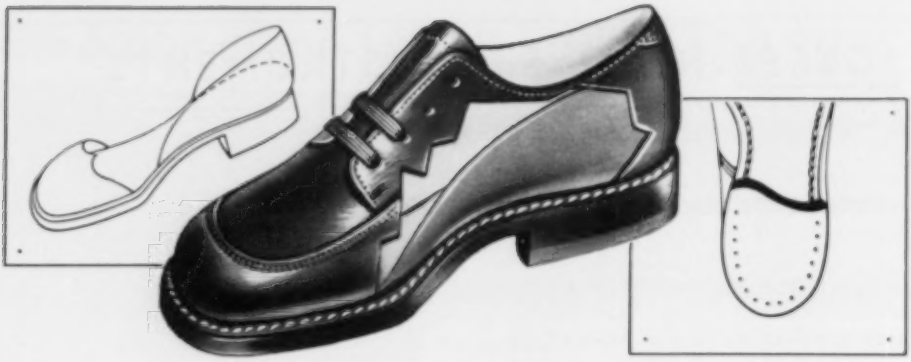

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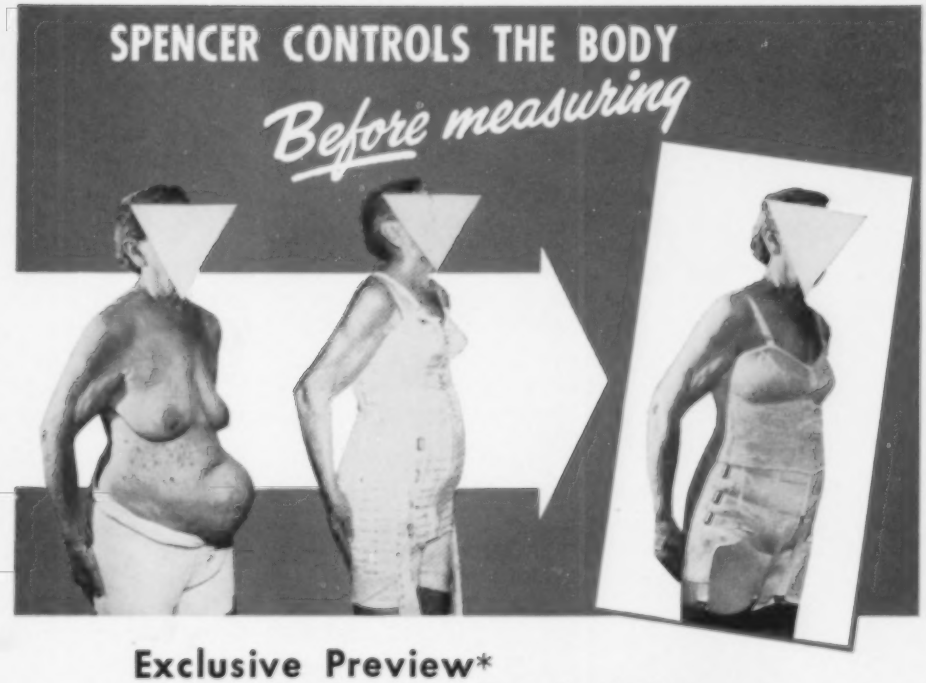

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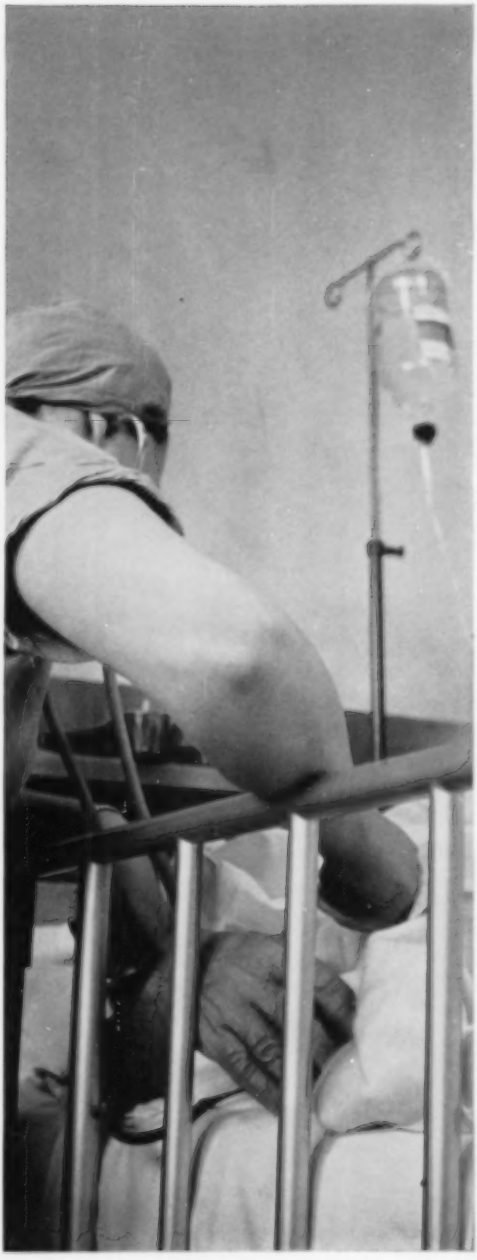

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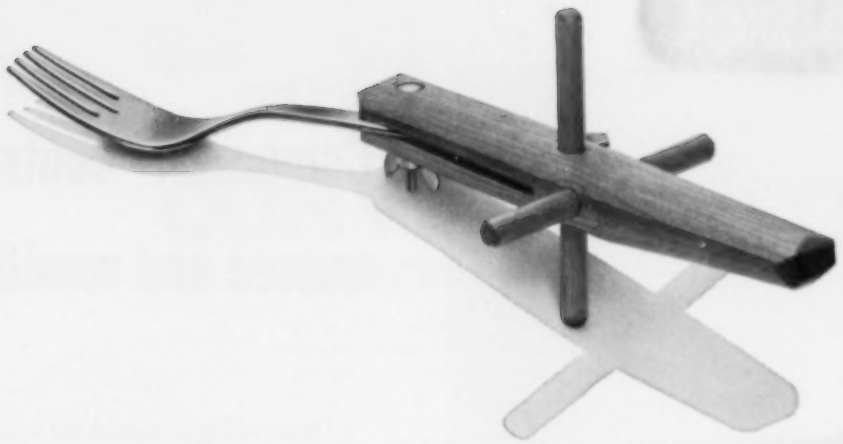

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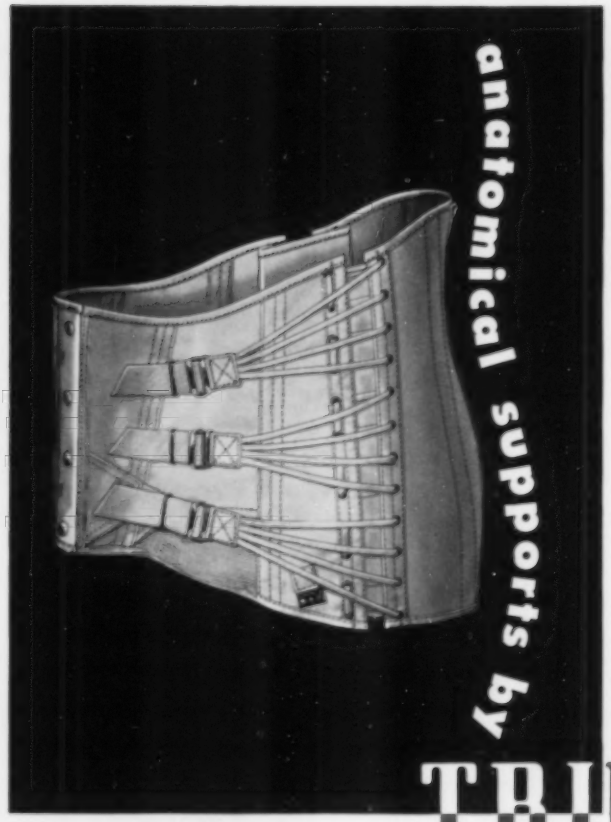

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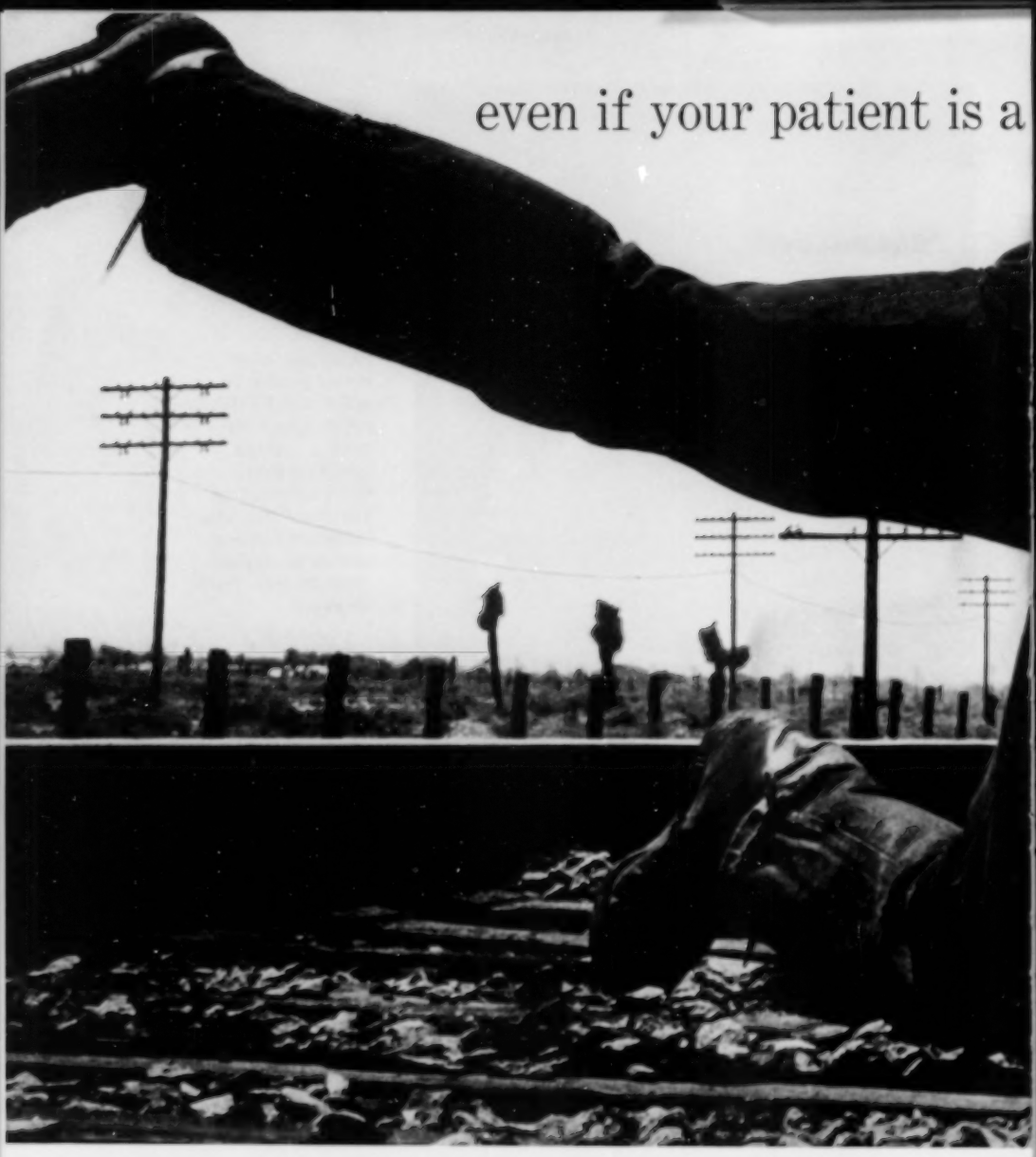

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VOL. 40-A, NO. 5 OCTOBER 1958

The Journal of
Bone and Joint Surgery

American Volume

Reversibility of Pregangrene in the Severely Ischaemic Limb*

BY A. W. HUMPHRIES, M.D., V. G. DEWOLFE, M.D., AND F. A. LEFEVRE, M.D.
CLEVELAND, OHIO

From the Department of Vascular Surgery and the Department of Cardiovascular Disease, The Cleveland Clinic Foundation, and The Frank E. Bunts Educational Institute, Cleveland

In recent years, the replacement of diseased major arteries has attained a secure place in the surgical armamentarium. Direct arterial replacement is now the treatment of choice for aneurysms in all locations other than the head, and it frequently is the preferred treatment for intermittent claudication. Much has been written during the past few years concerning these conditions, but little has been said in regard to the place of arterial surgery in effecting reversibility of pregangrene in the severely ischaemic lower extremity.

Partial or complete occlusion of the major arteries that supply the lower extremity results in a diminution of blood flow to the limb. The arteries most

FIG. 1

* Read at the Annual Meeting of The American Academy of Orthopaedic Surgeons, New York, N. Y., February 3, 1958, and at the meeting of the Central Surgical Association, Columbus, Ohio, February 21, 1958.

frequently involved are the aorta, the common iliac arteries, the external iliac artery, the hypogastric artery, and the superficial femoral artery.

Critical interference with blood flow to an extremity may be sudden or gradual. Sudden occlusion may result from an embolus, which generally arises within the heart, or it may result from the superimposition of thrombosis *in situ* (Fig. 1) upon a previously existing arteriosclerotic area of the artery. In either event sudden total occlusion of the main artery results in an essentially ischaemic limb, since collateral circulation does not have time to develop sufficiently to take over the supply of blood to the lower extremity (Fig. 2). In certain instances the use of lumbar sympathetic blocks may permit the development of enough collateral

FIG. 2

Occlusion of aorta at the level of the third lumbar vertebra. The vessel descending through the abdomen is the inferior mesenteric artery. No collateral vessels are seen.

circulation to maintain the life of the limb. In most instances, however, collateral vessels do not have time to enlarge before death of the limb occurs and amputation must ensue.

In these severely ischaemic limbs, early definitive arterial surgery is imperative. This consists in embolectomy or thrombectomy, with repair of the original vessel, if the quality of the artery is good, or the replacement of certain portions of it by arterial graft if the vessel is too sclerotic for satisfactory primary repair. It generally has been said that from six to eight hours after embolic occlusion is the upper limit of time during which embolectomy may be successfully accomplished; actually, the period of grace is much longer than this. Of thirty-four embolectomies performed during the past four years, only one embolectomy was unsuccessful when done within the first twenty-four hours; approximately 50 per cent were successful at forty-eight hours, and one was successfully accomplished as late as eighty-three hours after embolism. However, it is desirable to re-estab-

lish blood flow as soon as possible, since nerve and muscle ischaemia start to appear at approximately the eight-hour period. After that time, the limb may be expected to show local swelling of muscle, some involvement of the distal sensory nerves, and some interference with motor function lasting for several weeks, several months, or even permanently. Muscle contraction, equinus deformity, and foot-drop may eventuate. However, the need for a drop-foot brace, a tendon transplantation, or an ankle arthrodesis is a small price to pay for preservation of a limb. As a rule, if blood remains fluid in the veins of the foot, no matter how poorly they may fill, the chances are good for restoration of the limb by arterial surgery.

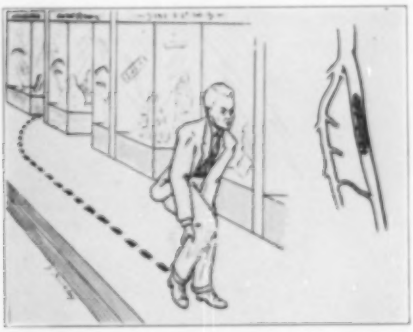

FIG. 3

FIG. 4

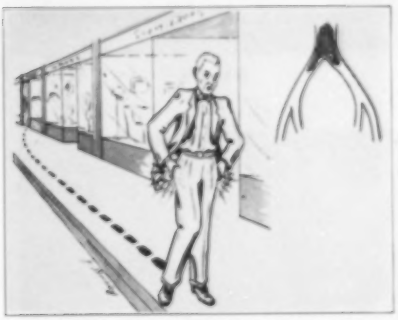

FIG. 5

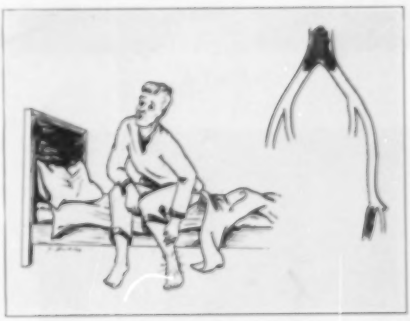

FIG. 6

Whereas sudden occlusion accounts for a relatively small percentage of the total number of amputations, the slow progressive arteriosclerotic occlusion in older patients is the most common cause of amputation. Since the vascular lumen narrows gradually, there is both a need for bypassing collateral vessels and time to allow them to form. Thus, when occlusion of the artery is finally complete, collateral circulation may have developed to such an extent that the only symptom of occlusion is intermittent claudication. This will appear in the calf (Fig. 3) if the occlusion is in the femoral artery; in the hip (Fig. 4) if the occlusion is in the iliac artery; or in both hips or the low back (Fig. 5) if the occlusion is in the aorta. When the occlusion is segmental in nature, one may expect arterial repair to result in satisfactory re-establishment of blood flow. Partial interference with main arterial blood flow is the cause of true intermittent claudication. In approximately 1,000 patients studied by arteriography in more than 500 of whom arterial-grafting was done, we have demonstrated in all sufficient diminution of blood flow to explain the symptom.

It must be clearly understood that intermittent claudication is not an end result in itself but is the first symptom of decreasing blood supply to the lower extremity. Its presence implies sufficient blood flow to keep the limb alive,

FIG. 7-A

FIG. 7-B

FIG. 7-C

FIG. 7-D

but insufficient flow to supply the demand of muscles under continuous work such as occurs in the muscles of the lower extremity during uninterrupted walking. Rough measurements of blood lost from transected arteries indicate that perhaps as much as 75 per cent reduction in the normal flow must occur before intermittent claudication appears. In many patients the occlusive nature of arteriosclerosis obliterans is progressive, although the rate of progression varies greatly in individual patients. The extension of the local occlusion may be due to advancement of the disease process itself or to clotting of relatively stagnant blood in the region of the occlusion. It also may be due to the development of another occlusion at another level within the extremity. The result is further diminution

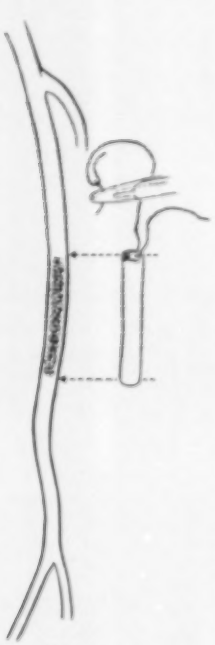

FIG. 8-A

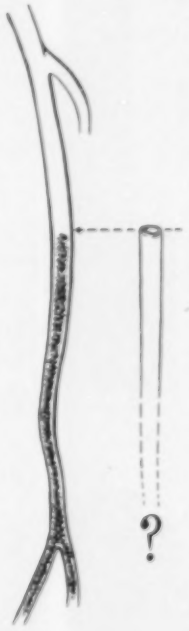

FIG. 8-B

in blood flow to the more distal parts and the patient's walking distance decreases. When the loss of blood flow reaches a certain level, a new symptom—that of rest pain—occurs (Fig. 6). Ischaemic rest pain in the foot when the patient is lying down denotes that blood flow has decreased to the point at which the effect of gravity makes a critical difference: when the patient reclines, the arterial flow is not adequate to supply the metabolic needs of the foot at rest; when the leg is hung over the side of the bed or when the patient stands up, the added force of gravity increases blood flow to the extent that these resting needs are met. Obviously, when this occurs, the extremity is approaching a critical stage and, as one would expect, severe claudication has developed.

If a patient with rest pain sustains even a trivial injury to the foot, the resultant break in the skin may not heal and an ulcer may form. Finally, as the condition progresses even the additional help of gravity will not supply the metabolic demand and gangrene supervenes. Many variations in this pattern occur. Sudden thrombosis *in situ* may precipitate death of the limb. Sudden occlusion of terminal vessels to skin, to muscle, or to the toes may precipitate local gangrene of one part with viability of the rest of the extremity. On the other hand, the progression of the condition may stop spontaneously and a patient may remain at one stage for long periods of time.

FIG. 9 FIG. 10 FIG. 11

A. S., a man fifty-nine years old, was examined at the Cleveland Clinic in September 1957. He had a history of myocardial infarction seven years before, and intermittent claudication of the right calf, after walking two blocks, for two years. Ten weeks before examination he had sustained a bimalleolar fracture of the right ankle. On removal of the cast, an ulcer, approximately two centimeters wide, was seen on the dorsum of the foot. During the following four weeks the ulcer grew larger and skin gangrene developed to the stage illustrated in Figure 7-A. At this time the patient experienced severe rest pain and he slept sitting up in a chair.

An arteriogram was made which demonstrated an occlusion of the superficial femoral artery from the inguinal ligament to the popliteal artery. The following day this segment was replaced with a homogenous graft. A dorsalis pedis pulse became palpable and on the seventh day the area appeared as illustrated in Figure 7-B. On the tenth day the area was debrided and a split-thickness skin graft was applied. Ten days later this appeared as illustrated in Figure 7-C. At three months the foot was healed (Fig. 7-D).

The occluded portion of the artery may be of definite length with patent vessel both above and below the limits of the occlusion (Fig. 8-A); this is called a segmental occlusion and is amenable to surgical treatment. The occlusion may extend distally throughout the length of the main vessel (Fig. 8-B); this is

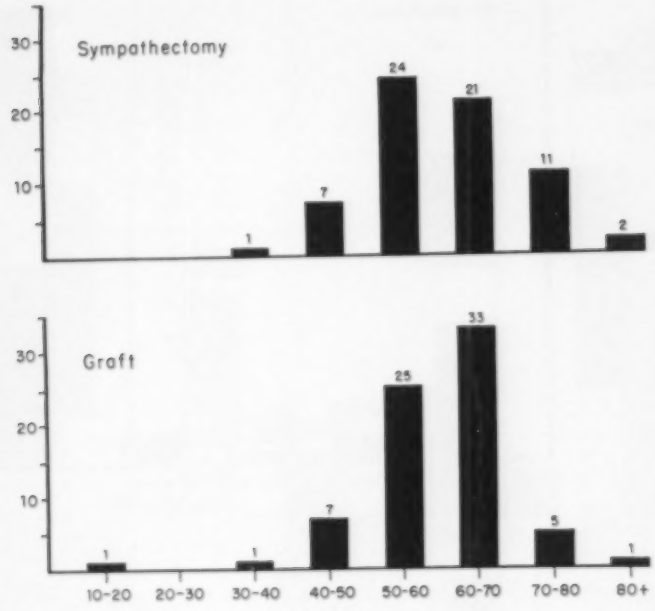

CHART I-A

The upper bar graph indicates the number of patients in each age group by decade in the sympathectomy series and the lower graph shows the number of patients in each age group by decade in the graft series.

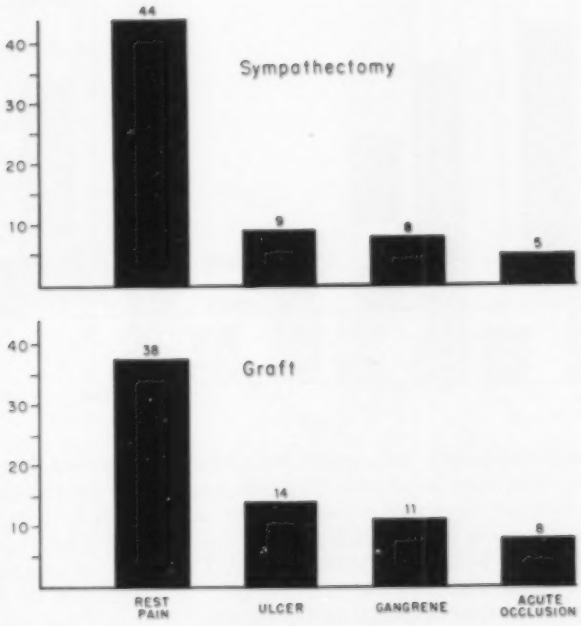

CHART I-B

The upper bar graph indicates the number of patients in each of the four categories of (1) rest pain, (2) ulceration, (3) gangrene, and (4) acute occlusion due to thrombosis *in situ*, in the sympathectomy series, whereas the lower bar graph shows the number of patients in each of these categories in the graft series.

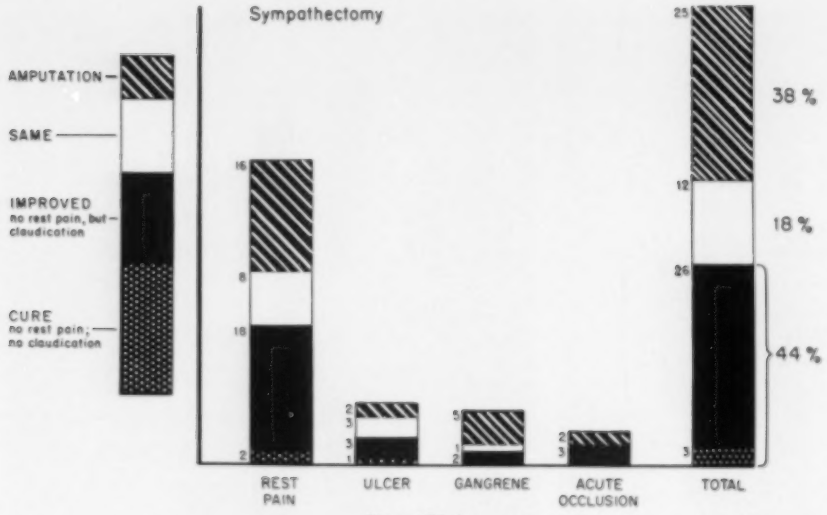

CHART II-A

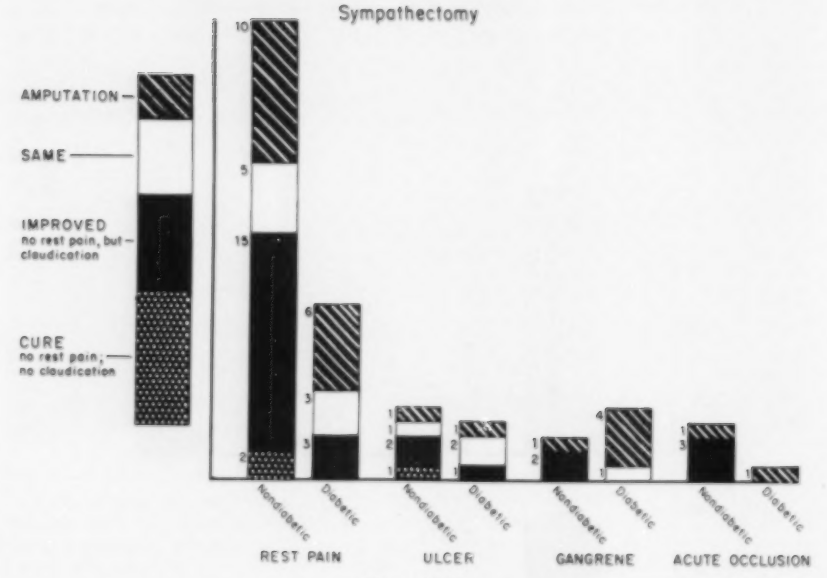

CHART II-B

called a non-segmental occlusion, and in the absence of a patent lumen distally to which a new vessel may be attached, it is not amenable to direct surgical treatment. On the basis of history or physical examination, we have found it impossible to establish criteria to determine whether the occlusion is segmental or non-segmental in nature. We must, therefore, depend upon either arteriography or direct surgical exploration. We use arteriography as a standard procedure and must sometimes resort, in addition, to exploration. If an arteriogram shows an obviously adequate outflow (Fig. 9) an attempt at grafting is done as a primary procedure. If an arteriogram shows an obviously non-segmental occlusion (Fig. 10), grafting is not considered and a sympathectomy usually is performed on the principle that it may lower the level of eventual amputation even if it does not

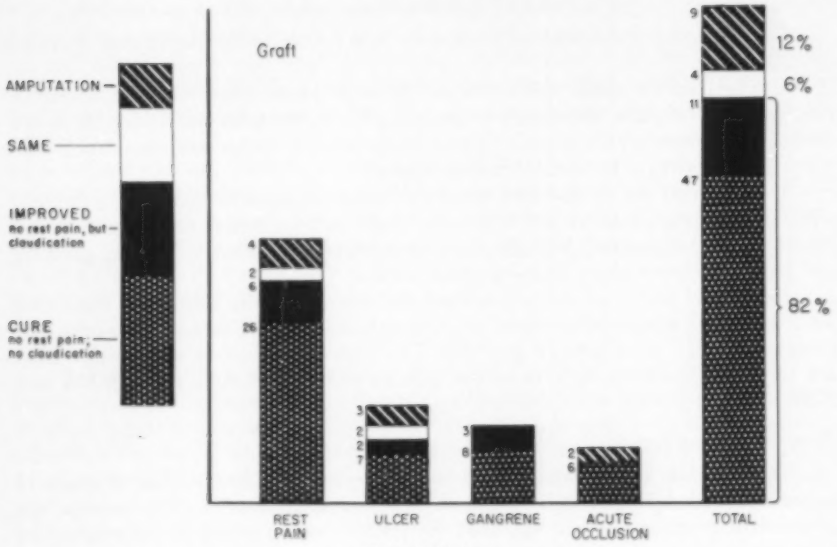

CHART III-A

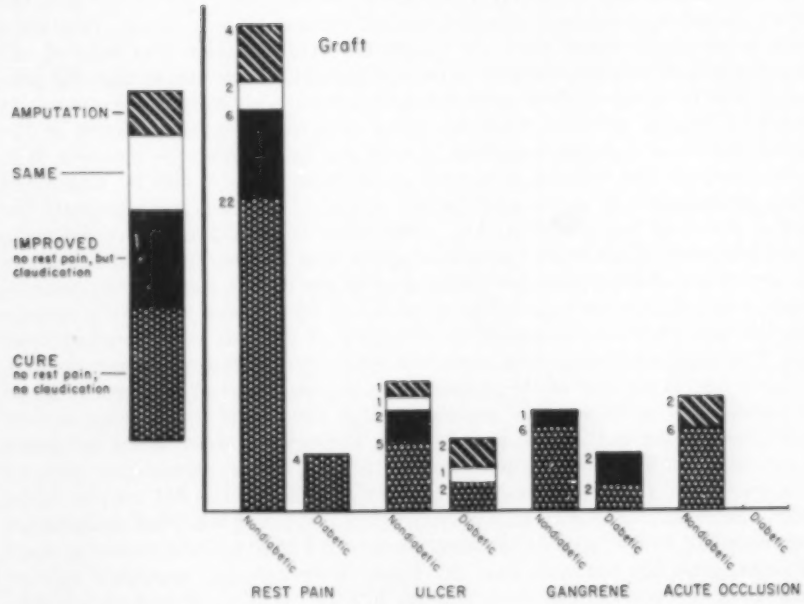

CHART III-B

succeed in saving the limb. When an arteriogram is equivocal (Fig. 11), we frequently resort to distal exploration in the lower portion of Hunter's canal or in the popliteal space. The artery at the distal end of the occlusion is transected and the outflow in the patent vessel below this point is evaluated. For this purpose, at the present time, we are using a pump that delivers blood under measurable pressures and that also measures the flow of blood per impulse beat. If the run-off is high, a graft is indicated; if it is low, a sympathectomy is indicated. In unusual cases when we are still undecided, both graft and sympathectomy may be employed.

RESULTS

In discussing the results of treatment, two points should be clearly emphasized:

1. The patients under discussion are those in whom disease has advanced to the stage of rest pain, ulceration or gangrene, or acute total occlusions have occurred due to thrombosis *in situ*. (The embolic occlusions are not considered here since they usually are treated by embolectomy.)

2. In no way do we discount sympathectomy. Sympathectomy has a definite place in the treatment of the ischaemic limb, and we resort to it many times. Nevertheless, when arterial-grafting can be accomplished, the results from grafting are far superior to those from sympathectomy.

Results of grafts in seventy-one consecutive ischaemic limbs are compared with a similar consecutive series of sympathectomies for ischaemia performed prior to the advent of arterial-grafting. Although each series is consecutive both are surprisingly comparable as to the type of patient involved (Charts I-A and I-B).

Sympathectomy Series

In Chart II-A the patients are grouped according to the four degrees of ischaemia and to the result obtained after sympathectomy. The results are grouped four ways: *Cure* means that the patient was relieved of ischaemia and of intermittent claudication—in other words, he has a completely useful extremity. *Improved* means that the severely ischaemic element was relieved but that the leg continued to claudicate after the patient walked some distance. This obviously is an improvement since the imminence of amputation was relieved, although the limb was not restored to normal function. *Same* means that the procedure had no obvious effect upon the limb. *Amputation* is self-explanatory. It should be pointed out that when the group of severely ischaemic limbs is discussed, the usual thoughts regarding success and failure must be reversed. It is to be assumed that without treatment all of these limbs would be amputated either immediately or in the near future. Amputation, therefore, represents the normal course of the condition. Any result other than amputation represents a saved extremity. When looked at in this light it may be seen that sympathectomy is a useful and efficient procedure, since only 38 per cent of the sixty-six patients required amputation during a follow-up period of up to seven years. It is obvious that the best results are obtained in the group of patients who have only rest pain. The patients having ulcer, gangrene, and acute occlusion did not do well. In this series, 44 per cent of the patients were improved and 18 per cent remained the same, while in 38 per cent amputation was done. This is a salvage rate of approximately one-half, which is very good. The striking thing about the group of patients who underwent sympathectomy is that, of the twenty-nine patients in whom definite improvement was obtained, in only three did normal limbs result. The remaining twenty-six were relieved of rest pain but all had claudication to some extent. In the majority claudication occurred after walking relatively short distances, generally less than one city block. Therefore, the extremity still remained a problem to each of these patients. In Chart II-B, these patients are subdivided into those with diabetes and those without diabetes. As one would expect, there is a lower percentage of improvement and a higher percentage of amputation in those with diabetes.

Graft Series

The follow-up period in the patients in whom grafting was done ranges up to four years (Chart III-A). As in the sympathectomy series, the best results were obtained in those patients with rest pain, since the arterial disease was by definition not so far advanced as it was in the other groups. However, the striking figure here is the number of patients who were relieved of ischaemia and intermit-

tent claudication, and in whom useful, normal limbs resulted. Of the thirty-two patients in whom improvement was gained in the group with rest pain, twenty-six had normal limbs and only six still had claudication. This is esentially the reverse of the figures for the results of sympathectomy. Also, in the patients who had ulcer, gangrene, or acute occlusion, a much higher percentage not only retained their limbs but also did not have claudication; therefore, the number of amputations was much lower. In this series, 82 per cent were improved (66 per cent with normal limbs) and 6 per cent remained the same, while in only 12 per cent was amputation done. Also, the results in diabetic patients were essentially the same as those in non-diabetic patients when grafting was done (Chart III-B). If blood flow can be re-established, the greater implication of disaster in the patient with associated diabetes does not apply.

SUMMARY

The over-all impression regarding the inevitability of amputation in the severely ischaemic limb must be re-evaluated in the light of the present practicability of arterial-grafting. In most of the patients the determination as to whether such a procedure should be contemplated is decided by the use of arteriography. This is a simple procedure and, since we now have a better than 75 per cent salvage rate in severely ischaemic limbs, we use it in all such cases as the single most important means of determining the form of treatment—grafting, sympathectomy, or amputation—to be employed.

Selected Aspects of Acute and Chronic Gouty Arthritis

An Internist's Interpretation of an Orthopaedist's Experiences with Gout and Gouty Arthritis *

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The diagnosis and management of the articular symptoms of gout are usually the responsibility of the general practitioner or the internist. However, the orthopaedic surgeon may be confronted from time to time with one or more aspects of the malady just as he is faced with a problem in differential diagnosis in patients subsequently shown to be suffering from acute rheumatic fever or acute rheumatoid arthritis—two of the more commom types of joint distress. The communication by Larmon and Kurtz in the July issue of The Journal has brought up-to-date the surgical management of chronic tophaceous gout and supplements the discussion by Linton and Talbott in 1943.

The Arthritis Clinic at the Buffalo General Hospital is especially interested in gout and gouty arthritis, and, because of this special interest, has had an opportunity to consider the varied problems of the patient with acute gouty arthritis as well as the patient with chronic tophaceous gout. The management of the chronic tophaceous state requires surgical intervention in a limited number of patients, and, until such time as prophylactic therapy encompasses the majority of patients suffering from gouty arthritis in the pre-tophaceous stage, surgical management will be indicated in the former category. It is gratifying to note that the experience of the Arthritis Clinic at the Buffalo General Hospital is consistent with the experience of Larmon and Kurtz in regard to the number of patients with gout in whom surgical intervention is required (approximately 10 per cent). Furthermore, the principles as outlined in their communication appear thoroughly sound and agree in all major details with my experience. Minor variations will be noted as the subject is developed.

DEFINITION OF TERMS

Gout is the generic term without reference to acute or chronic joint distress. Its use is justified in any patient who has suffered at least one attack of acute gouty arthritis. The only demonstrable abnormality in such an individual between attacks may be the increased concentration of uric acid in the serum and the disturbance of intermediary metabolism of uric acid [11]. If the patient is on a prophylactic regimen that enhances the excretion of uric acid from the body, even the concentration of uric acid in the serum may be normal. *Acute gouty arthritis* is self-explanatory. The *intercritical period* is the time between the acute attacks; in recent years, however, the term *prophylactic period* has been preferred because its emphasizes the value of medication which inhibits or prevents recurring acute episodes. *Chronic deforming gouty arthritis* or *chronic tophaceous gout* is the fate of only a small number of those afflicted. When it appears, it is a late manifestation. Several decades usually elapse following the first articular episode before this

*Studies pursued in this laboratory on the subject of gout were supported in part by a Grant-in-Aid from the National Institutes of Health, Public Health Service, Bethesda, Maryland.

stage develops. Equally significant is the fact that gout is not a chronic progressive disease in a majority of patients. Chronic tophaceous gout is not inevitable in the natural history of the malady if current principles of management are followed; chronic tophaceous gout should be the fate of a very small number of patients in the future. The designation *gouty diathesis* should be abandoned or re-defined. It is believed that the term should be used only in relation to phenomena intimate to metabolic gout. Coronary vessel disease, generalized arteriosclerosis, gastro-intestinal symptoms, cutaneous eruptions, and other clinical findings not directly related to articular gout have been classified as aspects of gouty diathesis without justification. The terms *urate* and *uric acid* are used interchangeably in this communication. The former term is preferred since the acid exists in body fluid in conjunction with the base. General usage, however, supports the retention of the term *uric acid*. An *uricosuric agent* is one that enhances the excretion of uric acid from the body. *Metabolic gout*, *primary gout*, and *familial gout* are synonymous terms and are employed to distinguish the more common type from gout secondary to an unrelated metabolic fault, usually a blood dyscrasia such as polycythaemia vera, myeloid metaplasia, or chronic myelogenous leukaemia.

DIAGNOSIS

Gout is not a rare malady and should be considered in the differential diagnosis of joint diseases, including traumatic arthritis.

Although the internist is the one usually faced with the establishment of the diagnosis of gout, the orthopaedic surgeon may be faced with the vagaries of the acute articular episode; he should appreciate the value of current therapeutic procedures, as well as possess the ability to rehabilitate joints in patients in whom the disease has progressed to the chronic tophaceous or the chronic deforming stage. Unless the physician, be he general practitioner or specialist, has an appreciation of the disease and the full potentialities of therapeutic management, the patient may be denied the benefits of advances which have made gout the most satisfactory type of joint disease to treat in contemporary medicine. The malady has been discussed recently in monographic form by the author [8], as well as presented as a symposium by a number of physicians especially interested in the dyscrasia [10]. No attempt will be made to consider, even in abstract form, all aspects of the disease in this communication. Selected phases only will be treated which are believed to be of particular interest to the orthopaedist.

Gouty arthritis should be considered in the differential diagnosis in any acute articular episode, sudden in onset, monarticular or polyarticular, especially in a male from adolescence through senility. There are several factors that should be considered in confirming or denying the possibility of gout. The ratio of males to females is approximately 20 to 1. It should not be forgotten, however, that the female is susceptible and that precisely the same criteria, somewhat more rigidly applied, hold. The familial incidence has been reported to be as high as 80 per cent and as low as 10 per cent. My experience agrees with the higher value. It is related to my interest in collecting familial data. The more careful the search for familial affliction, the higher is the incidence found. The number of relatives, without any clinical evidence of joint disease, of gouty patients with an increased concentration of uric acid in the serum is approximately 20 per cent. This observation supports the familial nature of the dyscrasia. It is interesting to note that, during the period of more than two decades that we have been collecting familial statistics, the development of an acute articular episode in non-affected relatives with an elevated level of uric acid in the serum, continues to be low. The chemical abnormality in non-affected relatives is not viewed with alarm, and no treatment is suggested until after the first attack of acute gouty arthritis.

Renal lithiasis, benign hypertension, and transient albuminuria may precede the first attack of gout. Since one patient in seven with gout will pass one or

more renal stones during the natural history of the malady, it is not surprising that some patients are troubled with this complication prior to the first acute bout. Albuminuria and a modest elevation of the blood pressure are observed in a number of patients with well documented gouty arthritis; in a few instances they may precede the first articular episode. The pathogenesis of these manifestations is believed to be related to the basic fault responsible for renal lithiasis, that is, an increased excretion of uric acid through the kidneys which insults, to a limited degree, the renal parenchyma.

The clinical characteristics of the acute attack are probably the most helpful criteria in the diagnosis. If I were forced to rely upon one diagnostic feature only, I would place greatest emphasis upon the clinical features of the acute episode. These may be observed by the physician at the time of attack, or they may be recounted in the symptom-free period, if the patient has been a critical observer. The cardinal signs of inflammation, redness, swelling, heat, and tenderness may be accompanied by elevation of body temperature to as high as 104 degrees Fahrenheit, leukocytosis, and increase in the sedimentation rate. The acute attack usually develops suddenly in a previously healthy individual, sometimes during the day, more often during the night. Although the acute attack characteristically is sudden in onset, instances have been observed in which the onset was subacute or even insidious in development. Partial or complete incapacity of the affected joint or joints, in the untreated patient, is the rule. Two other types of joint disease frequently encountered in practice, rheumatoid arthritis and osteo-arthritis, are not associated with overwhelming acute symptoms. On the other hand, acute rheumatic fever may simulate acute gouty arthritis and, therefore, poses a difficult diagnostic problem, particularly in the young male. Either malady may be migratory and polyarticular. Osteo-arthritis may be associated with an acute Heberden's node, but the localization of symptoms to the node rather than to the joint should be helpful in differentiation. The metatarsophalangeal joint of the great toe is a joint classically involved in gouty arthritis; more than 50 per cent of the patients will experience acute distress in this joint. The bunion joint is exquisitely tender, and street shoes cannot be worn with comfort. Inspection of the shoe may reveal an operation upon the medial aspects of the leather or even removal of a major portion of the toe of the shoe, hence, the designation *gouty shoe*. Casual observation of the shoe that the patient may be wearing, or inquiry regarding a shoe that may be left at home, if the patient is wearing a slipper, may offer confirmatory evidence.

The concentration of uric acid in the serum is of considerable value, but the data should be interpreted with circumspection. Serum, rather than whole blood, is preferred for the sample. The technical procedure in the biochemical laboratory is not always reliable; and, unless the technician is familiar with the possible sources for error in the determination, a false or an equivocal value may be reported. The reading is based upon the development of color and a number of substances may interfere with such a procedure. A false normal value may be reported if the patient has ingested one of a number of anti-arthritic drugs within a forty-hour period prior to the collection of the serum for the determination. It is interesting to note that most anti-arthritic agents, whether prescribed by the physician or ingested at the discretion of the patient as a home remedy, are uricosuric agents. Included are the non-specific rheumatic agents such as salicylates, phenylbutazone, and adrenal steroids. Each preparation is endowed with some uricosuric capacity; and, as the body fluids are depleted of uric acid, there may be a transient return of the serum uric acid to the normal level. Thus, it is best to wait forty-eight hours after the administration of any anti-rheumatic agent before collecting the serum for diagnostic interpretation. Colchicine, the only specific anti-gout agent, is endowed with no uricosuric properties. The upper normal limit for serum uric acid in males is 5 milligrams per 100 milliliters, and the lowest range in gouty males 6 milligrams per 100 milliliters. In females, this range may be slightly low-

er; clinical gout has been reported in females with a serum uric acid level of 5.5 milligrams per 100 milliliters. It should be noted also that a limited few non-gouty persons may have a serum uric acid level in the gouty range. The explanation for this is not forthcoming. The incidence is sufficiently high, however, to justify caution in basing a diagnosis of gout largely upon the level of serum uric acid. In substance, the clinical characteristics of the acute attack are more reliable in diagnosis than the serum uric acid (urate) level.

Roentgenographic changes, save for soft-tissue swelling, should not be expected until after the disease has been evident clinically for several years. It is believed that a significant quantity of uric acid must be deposited in bone or cartilage before roentgenographic changes appear. Such findings are characteristic of well developed gout and a number of attacks usually have preceded the development of this diagnostic feature. Essentially a similar statement may be made for subcutaneous tophi. It is unique to find tophi in the ears or tophi in periarticular areas at the time of the initial episode.

The use of colchicine as a diagnostic agent has merit. When a presumptive diagnosis of acute gouty arthritis is entertained, it is unnecessary to wait for the laboratory to report the serum urate concentration or the interpretation of the x-rays of affected parts. Specific treatment should be instituted without delay. Colchicine is the only specific anti-gout agent, and it has no recognized action in other types of joint disease. The response to colchicine, whether given orally or intravenously, may be extremely helpful in confirming the diagnosis as well as in alleviating the joint distress. It is imperative to prescribe a full course of colchicine, irrespective of whether diagnostic or therapeutic aid is sought. If colchicine is prescribed orally, one milligram should be recommended every two hours until the onset of nausea, vomiting, or diarrhoea. Usually the side action is apparent after the ingestion of not more than from four to six milligrams of colchicine. At this time the drug is discontinued and a gastric sedative prescribed and repeated if necessary. If the drug is given intravenously 1.5 milligrams of colchicine may be injected at three-hour intervals for two or three doses with similar results upon joint distress without the undesirable gastro-intestinal features.

The mechanism of the acute articular episode is unknown. Infiltration of cartilage and subchondral bone by urates surely precedes the first attack. Once the joint structures have been invaded, the urates persist except when there has been prolonged administration of uricosuric agents; however, the possibility of an acute attack is ever present. Increased precipitation of uric acid crystals preceding or during the acute episode has not been proved. Probably the precipitation is no greater during the acute episode than it is at other times. The polyarticular nature of many of the severe attacks suggest a systemic disturbance rather than an exclusively local one. Except for secondary changes attributed to inflammation, the physical appearance of articular tissue at the time of the acute attack is believed to be similar to that in the prophylactic period.

PRECIPITATING FACTORS

Precipitating factors may be of considerable help in suggesting the diagnosis especially for cases that may be encountered by the orthopaedic surgeon. Trauma to a joint, mild or severe, may cloud the issue from the beginning. There were several patients, in my series, in whom the first attack was precipitated by local injury. The diagnosis of a strain or sprain is more apt to be entertained than that of acute gouty arthritis. If the knee is the joint under consideration, a large synovial effusion, with or without gross blood, poses a knotty diagnostic problem whether it is the first attack or whether the diagnosis of gout has been established. There are no rules to be offered that will cover each situation. The number of sprains and strains and minor fractures in non-gouty individuals is greater than that in gouty persons, so that it would be folly to consider seriously acute gout

in each such orthopaedic problem. It is my practice in patients with known gout to treat the traumatic episode as if it were acute gout. The incidence of acute gouty arthritis following a surgical procedure, orthopaedic or non-orthopaedic, is significant. Because of the incidence of postoperative gouty arthritis, it is my practice to recommend 1.5 milligrams of colchicine daily, two or three days before the surgical procedure and two or three days postoperatively. If the operation is a major one, the colchicine is administered intravenously; otherwise, it may be administered orally. Any patient with a past history of acute gout should be so treated by the surgeon. Other precipitating factors include overindulgence in food and alcohol, acute infection—minor or major, blood loss, emotional trauma, and exposure to the elements. There are several drugs that deserve mention as precipitating agents—penicillin, ergotamine tartrate, vitamin B_{12}, mercurial diuretics, and thiamine chloride, each when administered intravenously.

PATHOGENESIS

Knowledge of the pathogenesis of the metabolic defect in gout is believed to be on firm ground as a result of investigations in the past decade. The increased concentration of uric acid in body fluid and the increased excretion from the urine in some patients is caused by increased urate formation. Diminished destruction and impaired excretion by the kidneys have been advanced in explanation but have not been supported by satisfactory experimental evidence. The destruction by the human organism of significant quantities of uric acid by an enzyme system, including uricase, is not of sufficient magnitude to explain the metabolic findings. The concentration of uricolytic ferments in human tissue is not high; nor has diminished excretion of urates by the kidneys been substantiated by unequivocal data. A small quantity of albumin in the urine and inability to concentrate solids is observed in a number of patients with gout. The clearance of uric acid by the kidneys, however, remains normal except in the terminal stages of a minority of patients who have renal insufficiency late in the course of the disease. Most of the patients, regardless of the stage of the disease, have a normal urate clearance and do not show a general or selective inability to excrete uric acid. It is believed that kidney involvement, when it is observed, is secondary to the metabolic fault and is not the primary dysfunction. There remains then, the hypothesis that increased formation of uric acid plays a part in the pathogenesis; there is much data in support of this explanation. A few patients with gout will excrete from two to four-fold the quantity of uric acid in the urine when comparison is made with that from a non-gouty patient [2]. This suggests increased formation of uric acid by the body. The non-affected relatives with an increased concentration of serum urate provide additional evidence. Lastly, conclusive support has come from investigators in several laboratories who have demonstrated an increased formation of uric acid in gouty patients by means of glycine labeled with radioactive or stable isotopes. These studies have been discussed at considerable length elsewhere [12] and presented in summary by Larmon and Kurtz.

PROGNOSIS

The prognosis in gout is excellent; in only a few patients does critical renal insufficiency develop. Less than 10 per cent of the patients suffer from chronic deforming gouty arthritis. There remain approximately 90 per cent of those affected who need suffer but an occasional attack of gout, if the prophylactic regimen to be discussed is followed. Not only is the incidence of acute attacks reduced to a minimum, but normal living in all respects is the rule. An occasional patient represents the exception. In my experience, the physician who seems to be rather prone to the malady may be such an exception. I attribute this to the teaching of antiquated principles of management of the malady in medical schools prior to the current generation of physicians, with the implication that little could

be done in management and the patient with gout must suffer the trials of Job.

MANAGEMENT

The large majority of gouty patients are cooperative and willing to follow the relatively simple prophylactic regimen. They lead normal lives and pursue gainful occupations. An optimistic prognosis was expressed a number of years ago [7] through the prophylactic use of colchicine daily. The future for gouty patients has been further lightened by the development of improved uricosuric agents [3, 6], especially probenecid. This powerful pharmacological agent was designed to inhibit the excretion of penicillin from the body. It was noted incidentally that it was endowed with uricosuric properties. Probenecid has been available for more than eight years [9], and the longer the drug is used, the more convincing are the clinical observations and the greater the respect afforded it. The toxicity of probenecid is low, probably no greater than is observed in the use of pharmacological quantities of salicylates.

In the prophylactic period, the combination of colchicine and probenecid is recommended. It is gratifying to note that there are several patients with gout in my series, more than eighty years of age, some still gainfully employed, and a few patients who are older than eighty-five years, physically active and mentally alert.

Colchicine is the drug of choice in the treatment of the acute attack, regardless of whether the diagnosis has been confirmed or is merely presumed. It is our practice to prescribe a full course of colchicine—four to six milligrams over a period of from eight to twelve hours. If the diagnosis has been established and one does not seek confirmation, the treatment of the acute attack may be modified by the prescription of submaximal doses of colchicine combined with phenylbutazone. If less than the full therapeutic amount of colchicine is prescribed, from 400 to 800 milligrams of phenylbutazone may be recommended daily for two or three days. There are some rheumatologists who prefer to use phenylbutazone exclusively in the management of the acute attack. In such circumstances, from 400 to 800 milligrams of the preparation is prescribed daily for two or three days. If the acute attack has been untreated, or poorly treated, for one or more days, more rigorous medication is indicated. In addition to a full course of colchicine, supplementary treatment with phenylbutazone or ACTH is recommended. If the latter agent is prescribed, from sixty to eighty units of ACTH-gel is given for two days. Intravenous injection of colchicine also has a limited but definite place in treatment. During the convalescence from acute gouty arthritis, early ambulation is encouraged. There are no other specific measures recommended for the treatment of the acute episode. General measures include an abundance of fluid, protection of affected joints, and an *ad libitum* diet.

The interval between attacks varies considerably. Several years may elapse in a person mildly afflicted. The patient with moderate or severe gout may experience several attacks per year if adequate treatment is not prescribed. Patients, in whom tophi have developed, have a more severe form of the malady and are more prone to suffer a higher incidence of acute attacks and greater incapacity per year unless prophylactic therapy is followed. Between the acute attacks, in patients without articular deformities, there are no subjective symptoms or objective findings save for the chemical abnormalities in the blood and urine.

The prophylactic management currently recommended is believed to represent as much progress in the treatment of this form of arthritis as the isotope investigations have contributed to the understanding of the metabolic dysfunction. Prevention of acute attacks should take precedence in emphasis over the management of the acute attacks; and, if the prophylactic regimen is respected, acute attacks should be infrequent in incidence and the patient should be symptom-free save for possibly a few days per year of minor articular distress. Although the

acute episode is a miserable affair if allowed to reach full proportions, proper respect for prophylactic agents will reduce the incidence of acute bouts to clinical insignificance. The recommended prophylactic regimen is simple to follow and permits the patient to lead a normal life and either stays or reverses the previously progressive effects of the disturbance of uric acid metabolism.

There are two drugs vital to the prophylactic regimen—colchicine and a uricosuric agent. Each drug complements the other. There is no overlapping of pharmacological action. Neither one by itself is as effective as the combination. The other anti-gout agents may be ignored in prophylaxis if colchicine and a non-toxic uriscosuric agent are taken daily. Although little or no effect upon uric acid metabolism may be attributed to colchicine, the value of the daily use of this preparation in the prophylactic period has been proved by experience. It is believed to be a good practice for each patient to take some colchicine regularly. If the gout is mild and the past history reveals that the patient has suffered less than one attack per year, one tablet of colchicine, 0.5 milligram, is recommended on each of three days per week. Patients moderately afflicted, those with one or more attacks per year, but without evidence of chronic tophaceous deposits, are advised to take one or two colchicine tablets each day of the year. The severely afflicted should take colchicine daily up to the point of gastro-intestinal tolerance. This may be two, three, or in some instances, four tablets each day. The incidence of acute attacks was reduced significantly through the prophylactic use of colchicine alone prior to 1950. Since that time, a further significant reduction in the incidence of acute attacks and an improved state of well being has been noted through the addition of a uricosuric agent. Tolerance does not develop and if an acute attack appears, a full course of colchicine is maximally effective, regardless of previous ingestion. Patients who have been on daily rations of colchicine for a decade or more receive the maximum benefit from a full course when this is prescribed. There are a number of patients in this clinic who have taken colchicine daily for more than twenty years. A large number have ingested colchicine daily for a decade. Another obvious gain in the ingestion of colchicine regularly is the advantage of having started a course at the earliest possible moment, should acute symptoms appear.

The addition of probenecid to the prophylactic regimen in 1950 made available a powerful uricosuric agent which complements the action of colchicine. Initially, we proceeded on the presumption that the larger the quantity of probenecid ingested, the greater the uricosuric action and the greater the inhibition of the tendency for urate precipitation in bone and soft tissues. Theoretically, this still appears sound, but our clinical experience has been satisfactory with slightly smaller doses. The average quantity for patients moderately or mildly afflicted is one gram of probenecid daily. The clinical benefit that accompanies the administration of probenecid and colchicine becomes increasingly more encouraging year by year. If the level of serum uric acid is in the high gouty range, that is, 8 to 12 milligrams per 100 milliliters, the ultimate level in the patient taking probenecid averages 6 to 8 milligrams per 100 milliliters. If the level of serum uric acid is 6 to 8 milligrams per 100 milliliters before probenecid was given the normal range is reached subsequently. No attempt is made to titrate probenecid dosage with levels of uric acid in the serum. There is sufficient fluctuation in the concentration of serum uric acid to make titration unreliable. A rule of thumb has been proved by experience to be thoroughly satisfactory; essentially the same number of probenecid tablets are taken daily as colchicine tablets.

In recent months a new uricosuric drug has been under study in our laboratory. The assigned name is benzmalecene and the chemical formula is N-(1-methyl-2, 3, bis-p-chlorophenylpropyl) maleamic acid. It is distantly related structurally to probenecid but appears to be endowed with enhanced uricosuric properties [1]. It has, in addition, an interesting side action. In a limited number of

gouty patients, as well as in non-gouty patients, a significant depression in the cholesterol content of the serum may be demonstrated following the daily ingestion of the experimental drug. The demonstrated effect upon serum cholesterol concentration may prove to be a valuable adjunct in the prophylactic treatment of patients with gout. Large vessel sclerosis has long been associated with gout and in a few patients has lead to fatal sequelae, such as the rupture of an abdominal arteriosclerotic aneurysm. Long-term study will be required to determine whether or not periodic ingestion of benzmalecene will influence the incidence of sclerosis of the blood vessels.

Rigid restrictions upon habits, good or bad, are not imposed. The patient is encouraged to eat a balanced diet, drink an abundance of fluids, and pursue any physical activity that suits his fancy. Only those items high in purine substances, such as liver, kidneys, sweetbreads, and anchovies, are prohibited. The high fluid intake is necessary in order to provide additional fluid for the increased excretion of uric acid in the urine. Since the solubility of uric acid in the urine is near the upper limit of normal, an augmented uric acid excretion must have a similar increased amount of fluid available for transport. Alcoholic beverages are permitted within the mores of the patient's family and environment. The increased loss of uric acid from the body following ingestion of probenecid persists as long as the drug is ingested. When the agent is stopped, there is a prompt return of the level of the serum uric acid to that before administration of probenecid, with the reversion of the serum uric acid concentration. This does not mean that the benefits during probenecid therapy have been nullified, but rather that the disturbance is a chronic one and with cessation of probenecid, the reaccumulation of urates in tissues begins anew.

The toxicity of probenecid is unimportant clinically. Originally, it was our impression that there was a slightly increased incidence during the first few weeks or months after beginning probenecid. This impression has not been confirmed subsequently. Bone marrow depression or liver damage has not been reported. A few cases of hypersensitivity have been observed. Usually, this may be corrected with appropriate management. The incidence of renal stones is significant, but in our series has not increased with the use of the combined agents. The tendency to renal lithiasis is inherent in any good uricosuric agent. Probenecid is a mild gastrointestinal irritant if taken in full therapeutic amounts on an empty stomach. Such distress may be prevented by the ingestion of the drug with meals. A number of patients taking probenecid and colchicine daily since 1950 have had little or no incapacity in recent years. In these patients there was a previous history of moderate or severe gouty arthritis; they had lost weeks or even months from work each year prior to the institution of the therapeutic regimen. A majority of our patients, regardless of the severity of the disease, average less than one day per year of incapacity because of acute gouty arthritis. This represents a striking change from the period before the institution of the combined therapy. It should be appreciated that probenecid is of no immediate value during the acute articular attack. When such develops, it is unimportant whether or not probenecid is omitted for a day. It should be resumed, however, during convalescence.

The length of time that a patient should be on the combined regimen has not been determined. It is our prediction that patients severely afflicted with gout will remain on probenecid and colchicine daily throughout the natural history of the disease. Those moderately or mildly afflicted are permitted considerable freedom. Patients with moderate gout may take probenecid and colchicine from time to time after the regimen has been followed regularly for two or three years. Since relapse is rapid, a person moderately afflicted should not stop taking probenecid for any period of time. Gout is a chronic disease and the disturbance of uric acid metabolism persists so long as the patient lives. The threat of an acute attack remains because of the increased formation of uric acid in the body.

SUMMARY

There are several features of gout and gouty arthritis of particular interest to the orthopaedic surgeon. A presumptive diagnosis of acute gout should be entertained in any unexplained acute inflammation of one or more joints, particularly in an adult male. A family history of gout, renal lithiasis, or other ancillary features, may be noted. Most important is a clinical description of the acute attack which displays the cardinal signs of inflammation and may be associated with pyrexia, leukocytosis, and an elevated sedimentation rate. Confirmation of the diagnosis rests upon a prompt response to a full course of colchicine. The level of serum uric acid is not a reliable diagnostic aid. Roentgenographic evidence in the earlier years of the disease is confined to soft-tissue swelling at the time of the acute attacks.

The pathogenesis of the acute attack is not known. The pathogenesis of the underlying metabolic disturbance is associated with an increased formation of uric acid by the body. Diminished destruction and impaired excretion by the kidneys as a cause have not been supported by contemporary research. Precipitating factors include surgical intervention, acute infection, emotional trauma, local trauma, and selected drugs administered parenterally.

The prognosis in gout is excellent if the prophylactic regimen is followed. This involves colchicine and a uricosuric agent (probenecid) administered daily in moderately or severely afflicted patients and less often in those mildly afflicted. If the prophylactic regimen is followed, little or no incapacity need result.

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Use of Cutis as an Interposing Membrane in Arthroplasty of the Knee*

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Arthroplasty has long been a challenge to the orthopaedic surgeon. Barton is credited in 1827 with the first such operation for ankylosis of a joint. Early reports indicate that surgeons were endeavoring to produce a pseudarthrosis or a nearthrosis which is generally considered a quirk of nature. Eventually the experimental studies of Phemister on new-joint formation justified the production of a false joint.

The necessity of an interposing membrane or material was always recognized; however, not all authors were in agreement as to the specific function of the interposing material. The common problem was prevention of bone contact and recurrence of ankylosis. The variety of interposing membranes or materials varied from the use of soft tissue by Murphy, chromicized pig's bladder by Baer in 1918, fascia lata by Putti in 1920, and shortly thereafter, in this country by Campbell[5] in 1921. Autogenous fascia lata then became the standard.

In 1940, the pendulum swung back. Campbell[6] reverted to inorganic substances and reported the use of a Vitallium cap to replace the femoral condyle. He readily admitted that the results were not as successful as those in fascia lata arthroplasty. The search continued and a rubber laminar interposing material was reported by Giangrasso in 1940. McKeever reported the use of cellophane in 1943; the use of nylon was reported by Burman in 1943 and by Kuhns in 1953. Walldius in 1953 described a full-hinge prosthesis as did Shiers in 1954.

The authors realize the controversial nature of the problem and not being exponents of arthrodesis in all weight-bearing joints, particularly when other joints of the lower extremities are involved, or their function impaired, have accepted the challenge and have reverted to the use of an autogenous substance as an interposing membrane in arthroplasty rather than further the cause of those who advocated the use of inorganic material. The authors reflect the attitude of Buxton in his Robert Jones Lecture of 1953, in which he referred to the "fantastic foreign bodies" being used and expressed the hope that a tissue would be found that would unite to human structures. Accordingly, the authors wish to report their results in four patients in whom a cutis or dermal graft was used as the interposing membrane in arthroplasty of the knee.

CUTIS AS AN INTERPOSING MEMBRANE

The cutis or dermal graft is skin from which the surface epithelium and most of the subcutaneous fat have been removed. Its use as a free graft buried in the body is not new. Otto Loewe reported it in 1913 and by 1929 he had specifically mentioned its use in arthroplasty of the knee joint. In 1924, Rehn also referred to its use as a lining membrane. Interest in the use of cutis or dermal graft was revived in the early fifties when its theoretical disadvantage of epidermoid cyst formation was discredited and the prerequisite of the removal of the epithelial layer was established. Credit for this trend belongs to the plastic surgeons who have used it as a contour repair tissue and for filling spaces. Cannaday in 1948 and Swart in 1952 reported use of cutis in ligamentous repairs.

*Read at the Annual Meeting of The American Academy of Orthopaedic Surgeons, Chicago, Illinois, January 30, 1956.

FIG. 1

Vertical section of the skin (× 34): epidermis and cutis layers are clearly identified. The zone of the cutis graft is in the deeper layer of the cutis, the superficial surface is placed adjacent to bone (*A*). The deeper layer forms the new gliding or joint surface.

The cutis graft is composed of the derma or true skin with the surface epithelium removed. The simplest and most satisfactory method of removing the epithelial layer is by splitting the skin or removing a thin split-thickness skin graft, which always includes a superficial layer of the dermis. For arthroplasty the material desired is the deeper layer of the derma with a minimum amount of fat but with the deeper, loosely arranged and more elastic layer (Fig. 1). This is composed of collagenous and elastic tissue, blood vessels and epithelial elements, the deeper portion of the hair follicles, sweat glands, and oil glands. A characteristic of the cutis which makes it desirable for arthroplasty is the elasticity resulting from the anatomical arrangement of the fibers in the skin. As pointed out by Langer and confirmed by careful sections taken parallel to the surface of the skin, there is an interlacing meshwork of both collagenous and elastic fibers the predominant pattern of which runs parallel with the direction of greatest tension. Unlike fascia lata the skin will stretch in all directions and will conform

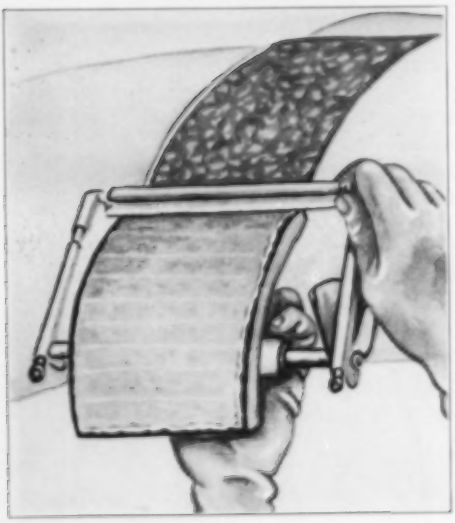

FIG. 2-A

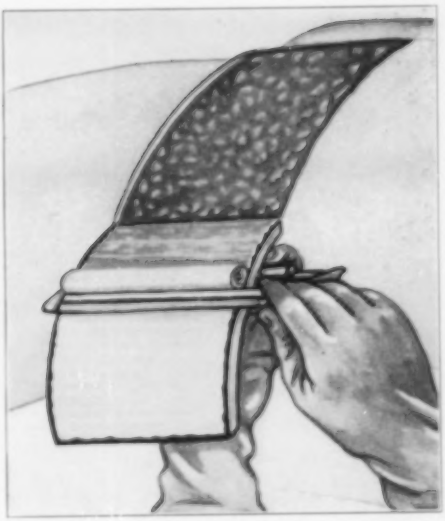

FIG. 2-B

Fig. 2-A: Removal of the full-thickness graft using the Padgett-Hood dermatone.
Fig. 2-B: The full-thickness graft remains adherent to the drum, the blade is reversed, the graft split at a more superficial layer, and cutis or dermal graft is obtained.
Fig. 2-C: The split-thickness graft is replaced and sutured on three sides to cover the donor area.

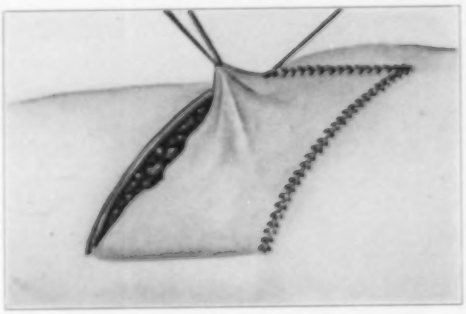

FIG. 2-C

to an irregular contour because of this arrangement of the fibers. Its elasticity, however, is greater in one direction than in another, again because of this fibrous-tissue pattern.

The superficial layer of the cutis is more dense and compact while the deeper layer is more loosely arranged and even includes fibrous septa extending into the fatty subcutaneous tissue. Experience has shown that grafts of derma take readily and remain viable when buried in the body just as do skin grafts on the surface of the body.

TECHNIQUE OF OBTAINING CUTIS GRAFTS

The cutis or derma to be used as a graft may be obtained by one of several methods. The one that the authors have found satisfactory and most simple is to use the Padgett-Hood dermatome (Fig. 2-A). The dermatome is set to cut the full thickness of the skin so that it will include a thin layer of the fatty subcutaneous tissue. A full drum of graft measuring four inches by eight inches is taken but the graft is left attached at the margin of the dermatome drum. The full-thickness skin graft thus obtained remains glued to the drum while the blade is repositioned to the original cutting position. The blade is readjusted to split the skin graft at a more superficial level. By cutting through or splitting the graft all the way to its attached margin, the cutis or dermal graft can be removed (Fig. 2-B). After hemostasis, the split-thickness graft is replaced and sutured on three sides to cover the donor area as a skin graft (Fig. 2-C).

An alternate method completely removes a full-thickness skin graft, with the dermatome, from the donor area. The blade is then reset to split the skin

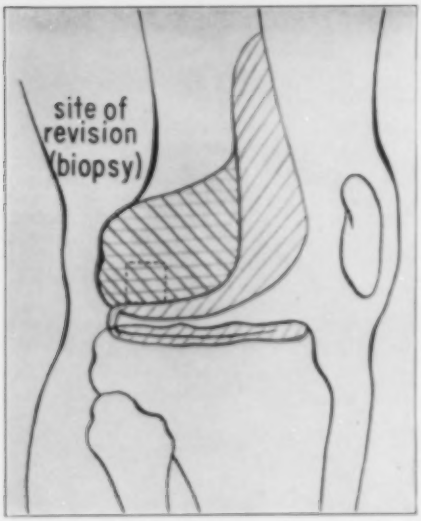

FIG. 3-A

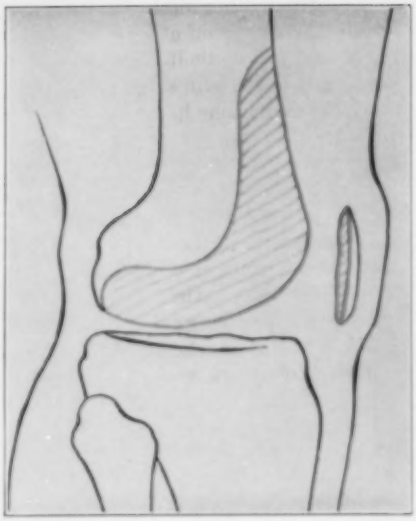

FIG. 3-B

Fig. 3-A: Case 1. Original graft coverage extended too high on the femoral condyles. Revision, as indicated, was done three years and three months postoperatively. Site of biopsy is also indicated.

Fig. 3-B: Case 2. Cutis-graft coverage includes the undersurface of the revised patella.

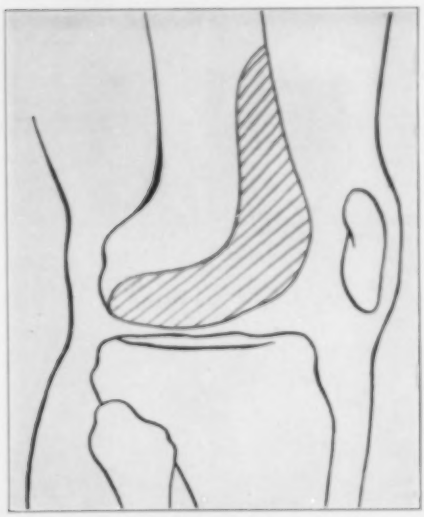

FIG. 3-C

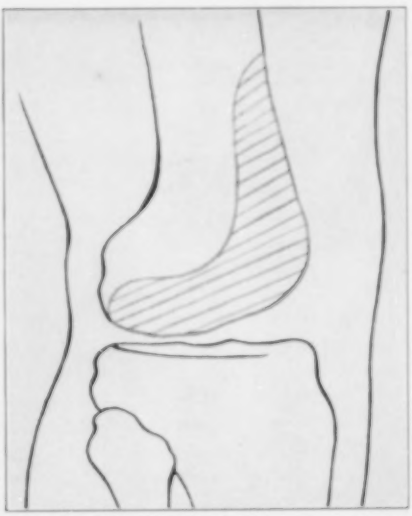

FIG. 3-D

Fig. 3-C: Case 3. Distribution of cutis graft.

Fig. 3-D: Case 4. Distribution of cutis graft. Patellectomy was performed at the time of arthroplasty.

without leaving the skin attached at one margin. In this method, the split-thickness skin graft is also used to resurface the donor area by suturing it on all four margins.

Another method consists in removing a split-thickness skin graft by any means and obtaining the cutis graft by sharp scalpel incision and dissection from the fatty subcutaneous tissue. The split-thickness skin graft is then used to cover the donor defect.

Still another method of obtaining the graft is to remove by sharp dissection a full-thickness skin graft with or without attached fat. The graft is then laid out flat and the epithelial surface painted with dermatome cement. The dermatome is glued to the skin surface and is used to split the skin. The fat may be removed by the dermatone before splitting the skin, or the fat can be removed by scissors or by sharp dissection. The split-thickness skin graft obtained may be used to cover the donor defect or, in certain instances, if the donor area is along the lateral portion of the abdomen, the edges may be undermined and the donor defect closed as a linear incision. If the latter is done, the split-thickness graft is discarded.

The most satisfactory donor areas for obtaining the cutis graft are in locations where the skin is moderately thick and where there is least hair. Areas where large sheets of graft may be best obtained are the lateral portion of the thorax, lateral portion of the abdomen, and upper lateral portion of the thigh or buttock, the latter especially in women for cosmetic reasons.

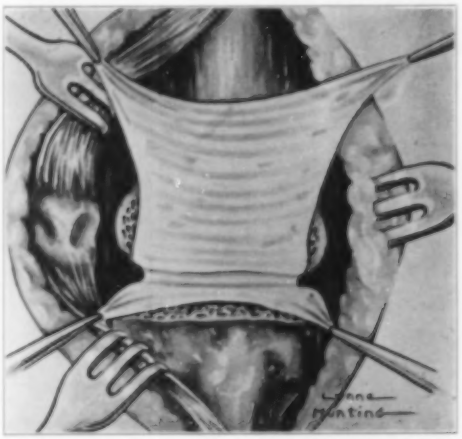

FIG. 4-A

TECHNIQUE OF ARTHROPLASTY

A tourniquet was used routinely and the knee joint was ex-

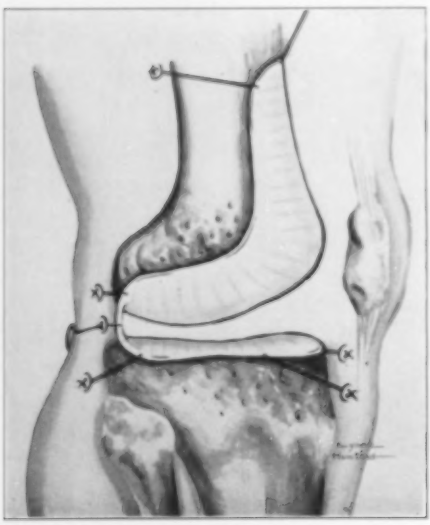

FIG. 4-B

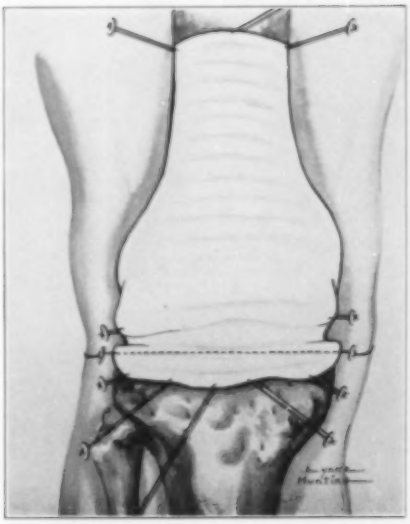

FIG. 4-C

Fig. 4-A: Insertion of graft into newly formed joint. The deeper layer of the cutis graft, with the fatty subcutaneous tissue, forms the new gliding joint surface. The superficial layer is adjacent to the bone.

Fig. 4-B: Pull-out wire technique. The graft is sutured at strategic corners to drape the graft over the bone surfaces. The wires do not penetrate or traverse bone. Wires are tied under moderate tension over buttons on the skin surface.

Fig. 4-C: Pull-out wire technique. The transverse wire (dotted line) functions as a "clothes line" hanging the graft in the posterior aspect of the joint. Excess graft is removed after all wires have been inserted.

FIG. 5-A

FIG. 5-B

Case 1. Preoperative roentgenograms.

FIG. 5-C

FIG. 5-D

Case 1. Postoperative roentgenograms.

posed through a long, medial parapatellar approach in all patients. When bony ankylosis was present, osteotomy was performed and the femoral condyles and tibial plateau remodelled into broad surfaces as proposed by Campbell [7], the femoral condyles being slightly convex and the tibial plateau being slightly concave. Adequate bone was removed, giving a joint space of at least three-quarters of an inch.

In the knees with fibrous ankylosis, joint débridement and complete synovec-

FIG. 6-A

FIG. 6-B

Case 2. Preoperative roentgenograms.

FIG. 6-C

FIG. 6-D

Case 2. Postoperative roentgenograms.

tomy were done. Little reshaping of the articular surfaces was required, but all cartilage was removed.

In one patient, patellectomy was performed, while in another a patelloplasty was carried out, the bone undersurface of the patella being covered with a cutis graft.

Collateral ligaments, when present and identifiable, were preserved and reattached to bone in the epicondylar region of the femur. In all cases, the cutis graft extended far enough proximally to restore a gliding surface for the quadriceps mechanism. The distribution of the cutis graft in each of the patients reported is demonstrated in Figures 3-A, 3-B, 3-C, and 3-D. The cutis graft covered the lateral aspect of the femoral condyle to the epicondyle in each patient; in only one was cutis used on both sides of the new joint. The graft should be sutured with such tension as to approximate its original size; it should not be applied drum-tight. It cannot be overemphasized that the elasticity of the cutis graft allows it to return to the original size taken from the donor site. The authors believe proper tension of the applied graft hastens revascularization and prevents formation of hematomata. Proper trimming and application will eliminate the necessity of revision. The pull-out-wire technique (Figs. 4-A, 4-B, and 4-C) is recommended to maintain the graft in position until it has taken. The wires do not traverse bone and are removed three weeks postoperatively.

In agreement with Speed we feel that detachment or lengthening of the quadriceps mechanism is inadvisable since it may lead to protracted convalescence, adhesions, and loss of maximum power of extension.

The superficial surface of the cutis graft should be placed in apposition to the bone, since the deeper, more elastic layer, containing minimum subcutaneous fatty tissue, is best suited for the new joint surface (Fig. 1). A pressure dressing is applied postoperatively.

POSTOPERATIVE ROUTINE

Immobilization of the reconstructed joint is desirable for a minimum period of three weeks to allow the cutis graft to take. This was achieved in two patients by the use of a voluminous compression type of dressing and immobilization in a traction-suspension apparatus, by means of a Thomas splint with a Pearson attachment. Traction (a minimum of three pounds) was of the skin type applied by stockinette and Padgett's glue. At the end of three weeks physical therapy and mobilization were started. Progressively increasing weight-bearing was usually allowed with crutches, after a six-week interval. Thereafter, the amount of walking and of support used depended upon the individual.

CASE 1. W. F., a white male student, eighteen years old, was first seen in June 1947. As a result of severe multiple osteomyelitis which began when he was twelve years old and finally healed when he was fifteen, there was bony ankylosis of both knees and the right hip, as well as deformities of both feet.

On October 22, 1947, a fascia lata arthroplasty of the right knee was performed. Then on June 11, 1948, a Vitallium-cup arthroplasty was performed on the right hip. Because of infection the cup was removed four months later.

Figures 5-A and 5-B show the preoperative roentgenographic appearance of the left knee. On March 4, 1949, cutis-graft arthroplasty was performed. A cutis-graft interposing membrane was chosen because adequate fascia lata was unobtainable. Four months later, on July 14, 1949, an old adherent scar which had broken down was excised. The scar, a residue of the osteomylitis, was on the anterior medial aspect of the upper portion of the left tibia. At this time a small piece of avascular bone from the anterior edge of the tibial plateau was removed and the patellar-tendon insertion was advanced distally.

On June 12, 1952, the cutis arthroplasty of the left knee was revised to correct the persistent instability of the collateral ligament which made it necessary for the patient to use a walking caliper brace. The excess cutis graft on the sides of both femoral condyles was removed to allow shortening of the collateral ligaments and reattachments to the femur (Fig. 3-A). After three months he discarded his brace and returned to school, using crutches part-time for walking some distance.

Follow-up evaluation of this patient (Figs. 5-C and 5-D) showed the following result on the side where the cutis graft was used.

FIG. 7-A

FIG. 7-B

Case 3. Preoperative roentgenograms.

FIG. 7-C

FIG. 7-D

Case 3. Postoperative roentgenograms.

Preoperatively (March 1949) there was bony ankylosis in extension, no pain, and no instability. The patient was unable to leave home or to dress and undress himself. When the patient was last examined, in November, 1955, the range of active motion was from 180 to 110 degrees with an arc of 70 degrees. There was slight pain on standing or walking. Instability was slight to moderate and there was genu recurvatum. The patient was able to work full time, as an accountant, and walked without aid both at his office and at home. He used crutches when walking some distance.

CASE 2. M. W., a white female, real-estate broker, forty-six years old, fractured the distal third of the left femur on September 30, 1947. When first seen on July 21, 1952, she had had seven operations on the distal portion of the left femur, including two bone-grafting procedures; there had been postoperative infection periodically. The limb was shortened two inches;

FIG. 8-A

FIG. 8-B

Case 4. Preoperative roentgenograms.

FIG. 8-C

FIG. 8-D

Case 4. Roentgenograms thirteen months after arthroplasty.

there was complete bony ankylosis of the left knee joint and persistent non-union at the fracture site. There was valgus deformity. On November 19, 1952, bone-grafting was done which corrected the angulation and non-union (Figs. 6-A and 6-B).

On October 13, 1953, cutis arthroplasty was performed. The donor site of the cutis graft was the right upper thigh. The graft coverage is shown in Figure 3-B. During surgery the quadriceps mechanism was noted to be fibrotic and almost non-existent. After the third postoperative week, mobilization of the joint was begun; weight-bearing was permitted after the seventh week. She returned to her work in one year (Figs. 6-C and 6-D). Evaluation of the patient showed the following:

FIG. 9-A

Case 1. Low-power photomicrograph (×21) of biopsy specimen taken at time of revision as shown in Fig. 3-A.

Preoperatively (October 1953) there was bony ankylosis in extension, pain only after continued use, and no instability. The patient did not work and used a crutch. When the patient was last examined in December 1955, the range of active motion was from 180 to 120 degrees, with an arc of 60 degrees. There was no pain and no instability. The patient had returned to work and used a cane only when walking on uneven terrain.

CASE 3. N. H., a white, electric lineman, twenty-six years old, sustained fractures of the left knee and ankle in a fall from a pole on September 11, 1948. When he was first seen by us on April 20, 1951, the left knee was stiff and painful. Bone fragments and the medial meniscus had been removed from the left knee shortly after the injury.

On June 21, 1951, a nylon sheet was used as an interposing material when arthroplasty was performed. Results were poor and one year later the fragmented nylon and dense fibrous adhesions were removed.

On November 12, 1953, a graft was taken from the abdomen (Fig. 3-C) and cutis-graft arthroplasty was performed (Figs. 7-A and 7-B). Three months later with the use of a cane, the patient returned to light work.

Preoperatively (November 1953) the arc of active motion was from 10 to 15 degrees. There were fibrous adhesions. Pain was moderate, but became severe on motion. In varus position there was slight instability. The patient was doing office work and walking with a caliper lock brace part-time and with crutches. When the patient was last examined in December 1955, the range of active motion was from 180 to 110 degrees with an arc of 70 degrees. There was occasional slight pain on prolonged standing or on walking. In varus position there was slight lateral instability. The patient was able to walk without the use of a cane both at home and at the office. However, for long walks or prolonged standing, a cane was used.

CASE 4. R. N., white male laborer, twenty-one years old, fractured the proximal third of

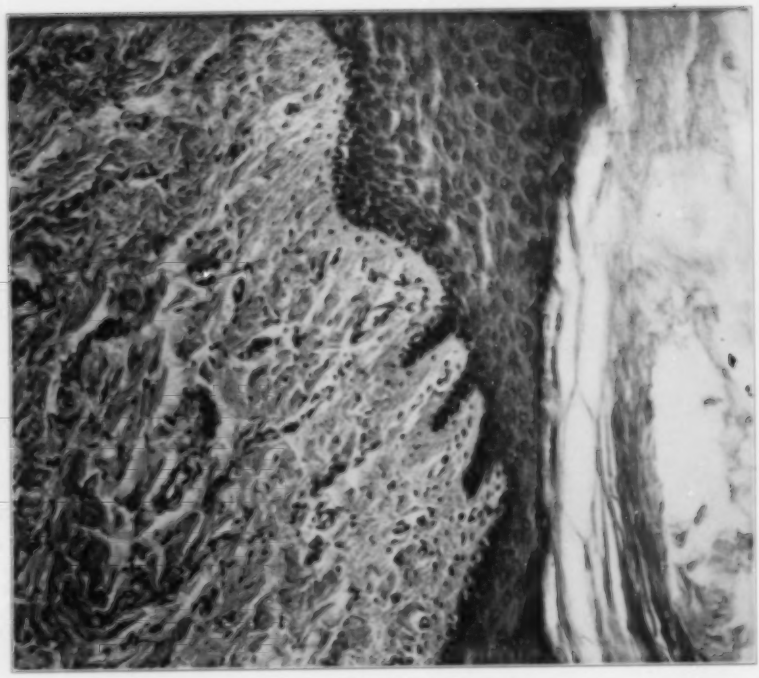

FIG. 9-B

Case 1. High-power photomicrograph (× 155) showing section of the cutis graft which had been inserted in this knee joint three years and three months prior to biopsy. Keratinized desquamated cells can be seen above the surface that represents the lining of the newly created joint. These cells are predominantly cuboid with their long axis orientated at right angles to the joint surface. The pathologist has referred to this surface as being covered with "what appears to be synovia."

both femora on October 17, 1951. On the right, the fracture was closed and comminuted, while on the left, there was an open comminuted fracture with extensive loss of soft tissue posteriorly, including the hamstring muscles and the sciatic nerve. By the time union of the femoral-shaft fractures was achieved, the patient had bilateral fibrous ankylosis of both knees. This was felt to be desirable in the left knee because of the sciatic-nerve involvement and the corresponding paralysis distally. The jog of motion in the right knee (Figs. 8-A and 8-B) was painful and severely handicapped the patient.

On November 11, 1953, quadriceps lengthening was performed; at this time the knee joint was inspected. Both menisci were absent and there were adhesions within the joint. The cartilaginous surfaces were destroyed for the most part. Postoperatively, the knee was stable and range of active motion was from 180 to 160 degrees with an arc of 20 degrees. However, pain persisted.

On March 3, 1954, cutis arthroplasty was performed. The donor site was the right lateral portion of the thorax (Fig. 3-D). The patella was excised and the defect left after the generous resection of bone was easily eradicated by apposition of the patellar tendon to the quadriceps tendon. The method employed was simple suture with reefing of the redundant overlying fascia. There was no modification in applying the cutis graft. After the third week the joint was mobilized; after the sixth week weight-bearing was permitted, at which time the range of active motion was 50 degrees. The patient began work as an automobile salesman six months after arthroplasty (Figs. 8-C and 8-D). Follow-up evaluation of this patient showed that:

Preoperatively (February 1954) the range of active motion was from 180 to 160 degrees. Pain was tolerable, but occurred with every step. There was no instability. The patient was unable to work or drive and used crutches. Postoperatively, in December 1955, the range of active motion was from 180 to 115 degrees with an arc of 65 degrees. There was no pain and no instability. The patient was working and used no walking aids.

All patients were improved and had returned to work. All results were rated

good with patients having at least 60 degrees of flexion in the knee on which we operated. The arthroplasties reported here met the requirements set forth by Payr in 1920 when he established the criteria for a good end result in arthroplasty of the knee—stability, absence of pain, and a 60-degree range of motion.

ADVANTAGE OF THE CUTIS INTERPOSING MEMBRANE

Cutis is an autogenous material readily available in abundant supply. Aside from the scar, no complications arose at the donor site, nor were there muscle herniations so frequently observed after removal of large segments of fascia lata.

Cutis is strong, tough, rubbery, and workable. It conforms to bone contours. It is easy to suture and does not tear in its longitudinal axis. It does not shrink to any significant degree; it takes as a skin graft and is acceptable to and tolerated by the host tissue without producing a significant foreign-body reaction.

CUTIS COMPARED WITH OTHER MEMBRANES AND MATERIALS

Fascia Lata

The supply of fascia lata is limited, indeed cutis was used in Case 1 because fascia lata was unobtainable. With fascia lata the defect at the donor site is undesirable; the muscle herniation may be disabling. Although it does have the advantage of conforming to bone contours, it is not as workable as cutis; it tears easily in its longitudinal axis. It does not withstand pressure well as shown by Miller and Friedman. It is acceptable to the host and is not a foreign body.

Nylon

Nylon, a synthetic material, is available in unlimited supply and requires no donor site. It is workable but wrinkles and does not conform to bone contours as readily as cutis; indeed molding it by the use of heat and electric cautery is difficult. It is moderately elastic, has good strength and withstands pressure well, but it cannot be anchored well to tissue and it acts as a foreign body. It may fragment.

Cellophane

Cellophane, a synthetic material, is not nearly as workable as nylon. Since it is brittle it tears readily and is practically impossible to sew. Its acceptance and anchorage to host tissue is very poor and it acts as a foreign body.

Vitallium

As in arthroplasty of the hip, molds or prostheses of Vitallium require alteration of the host bone in order to accept the element. An element manufactured specifically for the patient might eliminate this objection, but it would still act as a foreign body and its anchorage would depend upon the effect of the element on the body of the patient. We anticipate that enthusiasts of endoprostheses will offer in the future improved replacements for entire joints.

FATE OF CUTIS GRAFTS

The fate of the buried full-thickness autogenous-skin graft was studied in man by Peer[20, 21]. His observations were, in essence, that the autograft remained in place and fused with the surrounding connective tissue, and that soon after transplantation, the remaining epidermis formed closed cystic cavities of microscopic size which contained horny material and fragments of hairs.

Peer described histological sections made seven months and one year later; horny material was still seen in the cavities of microscopic size. These were surrounded by granulation tissue without epithelial lining. A microscopic study of sections of grafts removed at intervals after implantation, which varied from two weeks to twenty-eight months, showed that the epidermis was still present at two weeks and at one month. It was entirely absent in all subsequent studies. The

sebaceous glands were present at two weeks but showed definite degenerative changes. No sebaceous glands were observed in any of the later sections. Hair follicles were observed in all sections up to and including those examined at five and one-half months. They were absent in those examined twenty-eight months after implantation. Neither cyst formation nor malignant change was observed in any of the sections. The conclusions of these experiments conducted by Peer agree with the clinical experience of those plastic surgeons who have used dermal grafts.

Histologically, the fate of the cutis graft in the weight-bearing areas of the knee joint is unknown at the time of this report. As reported in Case 1, a portion of the cutis graft was removed three years and three months after it had been inserted into the knee joint. Microscopic examination of the specimen (Figs. 9-A and 9-B) as interpreted by Dr. Alan Moritz, Western Reserve University, is reported as follows:

Specimen was a portion of dermal transplant excised from the condyle of the femur incidental to revision of anthroplasty.

Most of the dermal transplant is now represented by a richly vascularized layer, about four millimeters thick, of fibrous connective tissue having one free surface covered by what appears to be synovia. The other surface has been created surgically and represents the lining of the newly created joint and is covered by a well defined, stratified layer of small cells. The most superficial of these cells are predominantly cuboid or low-columnar and their long axis is oriented at right angles to the surface. The surface has been rendered irregular by many small villous excrescences. The modified layer of cells covering these excrescences is in places sharply demarcated from the underlying collagenized connective tissue giving the appearance of transitional epithelium. The epithelial appearance of this layer is further enhanced by occasional crusts of what appears to be keratinized, desquamated cells. At one end of one of the transplants there is abrupt transition from what appears to be synovial membrane and what is clearly an epidermal surface. The epidermis at this end of the transplant is thick and covered by an abundant layer of keratinized cells. No glands and only one epithelial rest, resembling an atrophic hair shaft, are recognized.

The section of another portion of the transplant shows more pronounced villous irregularity of the surface, more pronounced exudative changes, and many collections of keratinized material in the depths of the tissue. There is a marked foreign-body reaction with giant cells in association with the rests of necrotic keratin.

Impression: (1) metaplasia of dermis with the formation of a synovial membrane, part of which is covered by recognizable epidermal cells, (2) occasional slight chronic inflammation and foreign-body reaction in response to necrotic keratin.

DISCUSSION

The authors believe that this report is justified because of the gratifying results obtained after adequate follow-up even though the number of cases is limited. It is our opinion that cutis should be suitable for any knee that is suitable for arthroplasty. Indeed its application may be extended to any joint in which arthroplasty is indicated.

Uncertainty about the fate of buried untreated cutis as reported by other authors [10, 11, 29] is not shared by the writers, who doubt that the cutis graft converts to tough, fibrous scar tissue. Rather, they believe, it takes as a skin graft and remains rubbery and elastic. Whatever epithelial elements may persist, such as hair follicles, have not caused any difficulty.

In contrast to nylon or other interposing membranes, it is thought that cutis does not cause the formation of a fibrocartilage covering of the moving joint surfaces.

Shrinkage in the cutis graft is not significant. Proper tension of the graft when it is applied, is thought to hasten revascularization and to prevent formation of hematomata. The newly constructed joint surface must be completely covered by the graft to eliminate the necessity for revision. Pull-out wires are recommended for anchorage of the graft. The superficial surface of the cutis graft should be placed in apposition to the bone since the more elastic layer of subcutaneous fatty tissue forms the best gliding surface for joint action.

The proper application of the transplanted cutis graft, with the superficial

surface adjacent to the bone, cannot be overemphasized. The importance of restoring a gliding surface over the distal portion of the femur for the quadriceps mechanism when the normal quadriceps pouch is obliterated has been emphasized by practically all authors who reported on the subject. Use of a cutis graft is suggested for quadricepsplasty and patelloplasty.

The operative technique of Campbell[7] has been used in these patients. The only change has been that a cutis graft was used as the interposing membrane.

The cases were evaluated by a critical comparison based on the amount of pain the patient experienced, preoperatively and postoperatively, as well as the range of active motion, the degree of stability, and the individual's capacity for work and walking with or without the use of aids, such as braces, crutches, or a cane.

The range of motion restored after cutis arthroplasty appears to be governed by the underlying pathological condition, the integrity of the muscles controlling the knee joint, and, of course, the technique of arthroplasty. Preservation of both the medial and lateral collateral ligaments, when present, is imperative in any arthroplasty of the knee.

SUMMARY AND CONCLUSIONS

Arthroplasty of the knee joint was performed in four patients with the use of autogenous cutis graft as interposing membrane. Preoperatively two of the knees had bony ankylosis, while two had fibrous ankylosis. Two of the four patients had other major disabilities involving the joints of the lower extremities.

The end results of all four arthroplasties were rated as successful considering the condition of these knees prior to surgery. There was no instance of re-ankylosis, epidermoid cyst formation, or wound infection. Range of active motion restored postoperatively varied from 60 degrees to 80 degrees of flexion; extension of 180 degrees was achieved in all cases.

Instability or hypermobility, especially laterally, was observed in one knee. This required revision which restored stability without decreasing the range of motion in flexion and extension.

The fate of cutis graft in the weight-bearing areas of the joint is unknown at this time. It is hoped that this preliminary report will stimulate others to use and to study cutis grafts in arthroplasty of weight-bearing joints.

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DISCUSSION

Dr. John G. Kuhns, Boston, Massachusetts: Dr. Brown and his associates described a new use of cutis, a readily available tissue, for interposition between the reshaped bone ends forming the knee joint. One cannot draw definite conclusions from four cases, but the results obtained so far are promising. The effectiveness of cutis as an interposing membrane will depend upon its adaptability to its new location and upon how well it withstands wear. Dr. Brown's study suggests that it unites readily to the synovial membrane and fibrous tissue about the joints, that it does not maintain any of the secretory or hair-forming functions of the skin, and that it does not form cysts. One would like to know whether it remains strong and elastic in the collagen diseases. If it fulfills these requirements, it is better than fascia, or any of the plastics that are now being used. We believe that normal cutis and normal fascia are superior to any foreign body. Our faith has been wholly with fascial, metallic, and plastic arthroplasties in chronic arthritis. Here, in this special disease, the patient's tissues have been found to be thin and deficient in elasticity. This has compelled us to use a foreign body—nylon membrane. After 110 nylon arthroplasties of the knee, we are still using it as the most satisfactory solution of our special problem. Nylon membrane will wear through in three to six years, although usually without symptoms as the forty-five patients who have good motion and are walking without canes six to twelve years after arthroplasty will attest. No matter what material we use for interposition, as we develop aptitudes and judgment, we can expect a useful, but never a normal knee joint. First, we cannot produce hyaline cartilage which is a necessary elastic buffer in weight-bearing joints. Second, nature, after long experimentation, as shown by comparative anatomy, never uses a hinge joint but a gliding type of mechanism in all weight-bearing areas. A hinge joint, however, is precisely the type of joint we get in man-made joints, no matter how well they are molded originally. In spite of these deficiencies, these arthroplasties function and withstand wear surprisingly well in knee joints which were originally destroyed or ankylosed.

Gastrocnemius Recession

Five-Year Report of Cases*

BY LUTHER M. STRAYER, JR., M.D., BRIDGEPORT, CONNECTICUT

A procedure for recession of the gastrocnemius was presented in 1950 [6] for the treatment of cerebral spastic palsy. First thought of as an anatomicomechanical method, it proved to be more important neurologically. The aim of the operation as finally appreciated and now advised is to release the insertions of the biarticular gastrocnemius and plantaris from tension on the tendo achillis until the foot is in dorsiflexion to 90 degrees or more. The plantaris is included not for strength, but for neurophysiological considerations.

Silfverskiöld was the first, in 1924, to separate the origins of the gastrocnemius from the condyles of the femur and to provide a physiological reason for the procedure. Vulpius, in 1920, suggested a method of tendo achillis lengthening, but it does not fulfill the requirements as does recession of the gastrocnemius in cerebral palsy because, after healing, tension is directly continuous to the gastrocnemius, as before the operation.

Recession of the gastrocnemius allows dorsiflexion of the foot to initiate proprioceptive sensory stimuli in the soleus only, until the foot reaches 90 degrees, that is, the gastrocnemius reflexes function at more than 90 degrees of dorsiflexion.

The operation was conceived as a result of army experience. Previously I had tested dorsiflexion of the foot with the knee flexed at 90 degrees, and had been impressed with Steindler's work [5]. Hence, the background was anatomicomechanical. The effects of the operation were more beneficial than the anatomical changes resulting from it warranted; this led to an inquiry into the possible neurological explanations.

Three neuromuscular concepts are of great importance. First, physiologists have shown that muscles contract isometrically, especially those which are biarticular. Second, proprioceptive impulses arise in muscles under tension, flow to the central nervous system, and modify muscle action. Third, decerebrate rigidity and the stretch reflex are greatly involved in patients with cerebral palsy.

The stretch reflex is normal; Sherrington was able to discover it only because he had a decerebrate animal. It is not a simple spinal reflex in patients with cerebral palsy for, under certain conditions, destruction of the vestibular (balance) nuclei abolishes rigidity. The attributes of the stretch reflex have been studied and recorded in decerebrate animals. Although most reflexes cause movements, for example, the knee reflex, the stretch reflex maintains posture. "Decerebrate rigidity is simply reflex standing," wrote Sherrington. Under experimental conditions the reflex results from stretching applied to the muscle itself; normally, gravity and proprioceptive impulses initiate the reflex. Hence it may be said that children with cerebral palsy have only the exaggeration of a normal response.

Recession of the gastrocnemius is designed to remove the stimuli which originate in the isometric, biarticular, antigravity muscles of the calf and which initiate proprioceptive impulses. By eliminating these impulses the vicious cycle of the stretch reflex is broken. In doing the operation it is easiest, after isolation of the sural nerve, to approach either side of the muscle belly, and to dissect from above downward to the attachment of the gastrocnemius to the soleus. After the tendon is severed, the gastrocnemius must be isolated inside the deep fascia by passing the finger up to the knee to break all fibrous bands passing to the soleus and to free the muscle from the sides of the fascia so that one can pass the finger entirely around the muscle. If the foot is then dorsiflexed there may be other bands including the plantaris longus muscle which must be cut to remove all con-

*Read at the Annual Meeting of The American Academy of Orthopaedic Surgeons, Chicago, Illinois, January 28, 1957.

TABLE I

PATIENTS IN GROUP I WITH SPASTIC PARALYSIS IN WHOM RESULTS WERE EXCELLENT[a]

(Average Age at Operation—3.7 Years)

Patient	Birth Date	Intelligence Quotient	Preoperative Symptoms	Date of Gastrocnemius Recession	Age at Operation	Postoperative Course
1 D.G.	4–2–45	High	Toe-walking with 10 to 15 degrees of flexion of the hip and knee; no adductor spasm	4–7–48	3	Casts for 4 weeks; child has good heel and toe action but flexed position of knee and hip remains; patient is extremely active, runs, and has achieved good practical gait (physical therapist report); follow-up at age 11
2 P.B.	1944	Low	Mild paraplegia, slight involvement of the hands; walked at the age of 2; first seen at age 6; toe-walking stiffly, could not stand still while erect without support; rejected by companions	5–9–50	6	Casts for 8 weeks; gait pattern tended to persist but patient could stand still with heels on floor without support; family pleased; follow-up at age 13 (7th grade)
3 R.D.	11–4–48	55 Very low; poor speech	Mild spasticity; extension tip-toe weight-bearing while held by parents under arms; had not walked preoperatively	1–11–51	2	Casts for 1 month; patient learned to walk independently but recurring epilepsy developed with cerebral degeneration; legs are now braced but child continues to use them well; he stands with heels on the ground; follow-up at age 9
4 B.R.	4–5–49	Greatly retarded	Mild paraplegia, more seriously involving the lower limbs; toe-walker when held under the arms without severe flexion of knees and hips	5–29–52	3	Casts for 4 weeks; patient had completely normal independent gait in 5 months; child has good personality; follow-up at age 7
5 R.K.	7–14–49	Impossible to measure; very high	Patient deaf and dumb; originally showed typical spastic extension of ankles, knees, and	8–5–52	3	Casts intermittently until July 1957; patient gradually lost fear, is unusually observing

			hips on being held in the erect position; adduction severe; flexion at the knees when weight was placed on the feet; no balance			has oriented himself entirely by sight; heels remain on the floor and patient can walk anywhere with his hands on back of chair or on parallel bars; no crutches or braces; follow-up at age 8
6 N.G.	9–29–51	57	Typical asymmetrical Little's disease of arms and legs; ankles, knees, and hips extended with additional spasm when held under arms	3–1–54	2	Casts for 4 months intermittently; patient has managed a completely independent gait with pelvic tilt; abduction of the hip and knee flexion on one side because of asymmetrical involvement; no crutches or braces; follow-up at age 5
7 D.C.	1–22–51	High	Typical Little's disease with ankle, knee, and hip extension when held under arms	7–22–55	4	Casts for 4 months; patient could stand holding on to furniture with confidence; can take as many as 90 to 100 steps independently; had tendency to fall and hit his head, but was doing this without fear; no crutches or braces; follow-up at age 5
8 A.A.	2–6–52	Very low	Typical bilateral Little's disease with extensor activity, marked when held under arms; patient was completely rigid before operation; had not walked	8–26–55	3	Casts for 8 months; no physical therapy postoperatively; patient left lying on floor at home; he learned to crawl and to draw himself up to erect position and stand with cylinder casts extending from the top of thigh to ankle; walked independently at this time; patient has microcephaly, almost unintelligible speech, and is still a behavior problem; leg function excellent; complete balance; no fear; follow-up at age 4

*The patient has achieved individual balance and can walk without the use of crutches or braces.

TABLE II

PATIENTS IN GROUP I WITH SPASTIC PARALYSIS IN WHOM RESULTS WERE EXCELLENT*

(Average Age at Operation—3.7 Years)

Patient	Birth Date	Intelligence Quotient	Preoperative Symptoms	Date of Recession	Age	Postoperative Course
L.F.	3-6-51	65 56	Bilateral spasticity of legs, none of arms; bilateral equinus deformity and mild talipes cavus; strabismus; speech excellent; when held under arms, legs were extended and adducted; no flexion deformity	4-13-54	3	Casts for 8 months intermittently; some valgus deformity of the feet developed; heels well down; Knight brace used to counter effect of hip flexion; release of peronaeus tertius; good balance; now walking independently with braces applied elsewhere for valgus feet, and with crutches; follow-up at age 5

*The patient has achieved individual balance but walks with the aid of crutches or braces.

nections between the gastrocnemius and the soleus, and fascia of the calf. Postoperatively a toe-to-groin cast is applied, which is replaced in four weeks by an ankle-to-groin cast. This is replaced as often as necessary until the knees remain straight without any flexion whatsoever.

The results of this procedure in patients with cerebral spastic palsy are gratifying. The patients fall into two groups: Group I including those who had not walked prior to operation, and Group II comprising patients who had walked at least in some fashion before operation. Results are measured in terms of progression in walking, not simply in terms of the effect on the local deformity. The results were classified as follows.

Excellent: the patient achieved balance and was able to walk without the use of crutches or braces.

Fair: the patient was able to walk effectively using crutches and braces.

Poor: no basic change in the patient's ability to walk resulted from the procedure.

Group I

In sixteen young patients who had never walked, the results are classified as *excellent* in twelve, *fair* in one, and in three, *poor*. The one patient with a fair result has left our clinic, but is walking well with braces and crutches. The residuum of cerebral symptoms in one of the patients in whom the result is poor is very low; another patient is a deaf mute; a third has retrolenticular fibroplasia, and is partially blind, but he can walk with help in parallel bars. There is reason to believe that the result in this child may eventually be fair or excellent.

Among those in whom the results are excellent are children with low intelligence quotients but good motor function. One child is completely deaf. It is apparent that patients operated upon before they have had an opportunity to develop an integrated pattern of posture have a better chance of being benefitted by the operation. Selection for operation cannot be made when the child is first examined, and unless nearly every child is operated upon, good results may be forfeited.

One child appeared to have too low an intelligence quotient to warrant sur-

TABLE III

PATIENTS IN GROUP I WITH SPASTIC PARALYSIS IN WHOM RESULTS WERE EXCELLENT*

(Average Age at Operation—3.7 Years)

Patient	Birth Date	Intelligence Quotient	Preoperative Symptoms	Date of Gastrocnemius Recession	Age at Operation	Postoperative Course
1 J.K.	2-20-43	43	Typical bilateral Little's disease, severe	8-30-50	7	Continued to have convulsions with some mental deterioration; no attendance at Clinic in the last 6 years; patient now can stand holding on to the back of a chair with some knee and hip flexion; heels can be placed on the ground; quadriceps relaxes with sagging at the knees after standing some time; failure was due to inadequate follow-up; follow-up at age 13
2 J.B.†	7-8-52	Good	Cerebellar-cerebral involvement; when held under arms, legs and arms spastic in extension; toe-walking if feet are placed on floor; extremely relaxed when supine; head unbalanced, unable to hold erect at first; arms severely involved, cannot use them for support	11-22-55	3	Casts on intermittently until present time; good progress, patient can stand erect with heels on the floor in a standing table; can hold head up for long periods of time; arms still not useful; purposeless movements continuous; family pleased; shows excellent promise of eventual training; follow-up at age 4½
3 J.S.	1-12-47	69	Typical Little's disease; knees, hips, and ankles in extension when held under arms; vision defective, militating against balance training	11-21-50	3	Casts intermittently for 5 months; patient learned to walk well in parallel bars, then became overweight and knee flexion became a problem; parents did not allow application of casts to keep knees straight, heels down; patient is lazy; Eggers operation under consideration; follow-up at age 9

*The patient has achieved individual balance but walks in parallel bars.

†This patient is included in the excellent group because when his hands are held on the parallel bars he can stand erect and make good leg movements. The change in the patient's attitude has been dramatic compared with his preoperative condition.

TABLE IV

PATIENTS IN GROUP I WITH SPASTIC PARALYSIS IN WHOM RESULTS WERE FAIR*

(Average Age at Operation—3.7 Years)

Patient	Birth Date	Intelligence Quotient	Preoperative Symptoms	Date of Recession	Age	Postoperative Course
F.H.	5-6-45	45	Premature infant; typical Little's disease; scissor gait, severe equinus deformity; could not walk; severe eye defect; strongly corrective glasses were fitted	8-8-50	5	Casts intermittently until August 1954; heels turned to 90 degrees satisfactorily; patient learned to walk independently between bars with the application of casts at intervals; severe family rejection; left Clinic; braces were applied elsewhere; heels remained corrected; walks well with crutches and braces; follow-up at age 12

*The patient has effective ambulation with crutches and braces.

gery, but operation was performed nonetheless and casts were applied to keep his knees straight. Due to a misunderstanding resulting from language difficulties the patient did not return to the clinic for eight months. Amazingly, he was walking about well, goose-stepping, and still in the casts. They were removed, and now he is walking almost normally with great independence. This suggests that these children are being handled too much. Perhaps the casts should be applied and the child allowed to learn to crawl and to pull himself to a standing position as other children do. It must be remembered that all children are born with bent knees and this gait sometimes persists for a long time in normal children. However, in these retarded children, in order to help their balance reflexes, their heads must be made level at the same time as initiation of erect posture. In addition, with the help of casts which are worn day and night while the children are growing, we must obtain a back-knee position of 5 to 10 degrees in order to allow these patients to maintain balance more easily. Casts cannot be removed by parents as braces can; constant maintenance of the cast will quickly establish the extended contour of the joint. Braces will not accomplish the purpose fast enough to save the child's balance pattern. It cannot be too much emphasized that if the child can stand erect with his heels on the ground and his knees in slight hyperextension, the chances are greatest that he can walk, almost, if not completely, normally. Usually no adductor spasm remains when these aims have been achieved.

Group II

In seven patients between the ages of ten and fourteen years, all of whom had walked in some fashion before operation, the results obtained were four good, one fair, and two very poor. Some of these children had had multiple operations before the gastrocnemius recession. All had some restriction of dorsiflexion of the ankle due to bone changes. In this group of older children who had carried their heads in a forward position with the hips and knees bent due to gastrocnemius spasm, the knees and hips could be straightened forcibly for short periods, but the patient felt that he was falling backward. This is due to the fact that the labyrinthine reflexes have become established with this flexed position as the habitual posture for balance. These children can never stand erect with the head in normal

TABLE V

PATIENTS IN GROUP I WITH SPASTIC PARALYSIS IN WHOM RESULTS WERE POOR*

(Average Age at Operation—3.7 Years)

Patient	Birth Date	Intelligence Quotient	Preoperative Symptoms	Date of Gastrocnemius Recession	Age at Operation	Postoperative Course
1 V.S.	6-15-43	33	Severe Little's disease; absolutely rigid when feet placed on floor and supported by hands placed under arms	3-2-49	5	Casts intermittently until October 1949, roughly 6 months; patient with casts could be stood in parallel bars; considerable heel spasticity and adduction remained; there was persistent personality degeneration; severe family rejection and neglect; has never made any progress toward independent locomotion; follow-up at age 13
2 P.R.	8-30-47	Too low to determine	Typical severe Little's disease with severe hearing loss and some vision impairment	3-2-53	5	Casts intermittently for 14 months; no progress; patient could never learn to balance at all; knees finally were straight at end of casting, but intelligence quotient was too low to allow any training; heels would go to 90 degrees at any time during this period; follow-up at age 9
3 G.G.	3-8-50	92	Severe Little's disease with retrolenticular fibroplasia; when held under arms the hips, knees, and ankles were in severe extension; however, when supine the patient was extremely relaxed	4-15-53	3	Casts for 11 months intermittently; knees in the casts straightened and equinus deformity remained corrected; however, the child was overindulged by the parents and little incentive to use parallel bars could be developed; training was poorly carried forward and patient has not made progress in independent walking in any fashion; follow-up at age 6

*There is no basic change in the patients' ability to ambulate.

TABLE VI

PATIENTS IN GROUP II WITH SPASTIC PARALYSIS

(Average Age at Operation—Twelve Years)

Patient	Birth Date	Intelligence Quotient	Preoperative Symptoms	Date of Gastrocnemius Recession	Age at Operation	Postoperative Course
1 T.A.	10-21-36	60	Severe Little's disease; Stoeffel's obturator neurectomy 1945 (patient fell off stretcher in hospital, causing aggravation of fear); adductor myotomy, 1952; osteotomy of femur, 1954; 30-degree knee-flexion gait with crutches and braces; ankles flex to 90 degrees only with knee bent	10-14-48	11	Primary result good with casts on legs 4 weeks; then knees began to bend and adductor spasm returned; failure caused because knees were not extended at time of gastrocnemius recession; patient stands with crutches and braces with knees flexed; poor result; follow-up at age 20
2 J.A.	8-25-37	68 79	Severe bilateral symmetrical Little's disease; triple arthrodesis on left, 1944, triple arthrodesis on right, 1946; 30-degree knee-flexion gait with crutches and no balance; ankle flexion to 90 degrees passively with knee bent	7-31-48	10	Casts for 4 weeks; immediate postoperative result favorable but knee flexion was not overcome; gradual personality collapse during adolescence; increasing knee-flexion deformity in spite of braces; patient finally walked with crutches and great effort; osteotomy of femur desired to extend knees; follow-up at age 19
3 C.C.	3-8-36	136	Moderate Little's disease more severe on right; Stoeffel's obturator neurectomy on right, 1941; patient walked stiffly with much scuffing with crutches and foot-drop braces	3-12-49	13	Casts for 4 weeks; result good; marked adhesions between gastrocnemius and soleus found at operation, not known if these were all released; marked gain in anterior tibial strength so that foot-drop braces gradually discarded; patient has gone on to college; follow-up at age 20

4 J.DeM.	4-20-39	36	Severe symmetrical bilateral Little's disease; bilateral Z-tenotomy of heel cords, 1943; patient then had no plantar-flexion power on right; walks without braces; 25-degree knee flexion; adduction gait	3-2-49	9	Casts for 4 weeks; immediate postoperative result favorable; knee flexion persisted, becoming much worse with adolescent gain of weight to 185 pounds; patient can walk with hips and knees flexed without braces; weight reduced to 135 pounds; patient recovering from osteotomy of both femora; follow-up at age 18
5 R.P.	4-4-38	High	Moderate bilateral symmetrical Little's disease; patient walks with braces and canes with hip and knee flexion 5 to 10 degrees	8-1-50	12	Casts for 8 weeks; no postoperative change in hip and knee flexion; increased anterior tibial strength but talus conformation does not allow dorsiflexion to 90 degrees; patient walks with crutches and braces; no change in gait pattern; follow-up at age 18
6 J.S.	6-12-41	?85	Mild bilateral Little's disease; flexion contracture of hip, knees, and feet; scoliosis corrected and spine fused, 1953; patient walked without support, severe scuffing	8-31-55	14	Casts for 4 weeks; improved dorsiflexion, less scuffing; talus conformation does not allow complete dorsiflexion; follow-up at age 15; patient walks independently
7 M.L.	10-24-37	High	Severe quadriplegia with mild athetoid movements; severe 30-degree flexion contracture of hips, knees, and ankles; patient walked with braces; bilateral Stoeffel's obturator neurectomy, 1940; triple arthrodesis on left, 1942; triple arthrodesis on right, 1944; ankle flexion to 90 degrees with knees flexed	10-27-48	11	Casts for 4 weeks; night splints, 6 months; postoperative gait improved with braces and crutches, less adduction; impossible to get head balanced erect; osteotomy, left femur, 1952; patient finished high school, is employed; gets around independently with crutches; follow-up at age 20

position without going through a distressing period of re-education. Few are successful in this process because the pattern of function of the vestibular nuclei and the labyrinthine reflexes in connection with the stretch reflex is too firmly established.

Although we have used the Eggers procedure and osteotomy of the femur in the treatment of flexed knees, these operations have not been done on the patients in this series.

With increasing experience the indications for gastrocnemius recession are becoming established. It is not indicated in patients with athetosis. One patient with spastic athetosis was relieved of his equinus deformity but he received no benefit because of an exacerbation of the athetosis.

Likewise the procedure has not been of particular value in adults with hemiplegia. In two patients in this age group there was a short period of improvement postoperatively but both reverted to their old habits. Nonetheless, in selected cases it may be indicated.

The procedure is chiefly indicated in a child with bilateral cerebral spastic palsy who is under six years of age and has never walked. The operation under these circumstances could be a worth while first step in the treatment when the following findings are present: (1) extensor spasm of the hips, knees, and ankles, with relative rigidity of the back, which develops when the child is suspended with the examiner's hands beneath the axillae; and (2) no gastrocnemius spasm when the foot is dorsiflexed above 90 degrees with the patient supine and the knee flexed to 90 degrees.

In infantile hemiplegia, improvement can be anticipated following the operation in every case, but without change in gait pattern. Of five such patients all were benefitted, although some more than others. In every instance the parents were pleased. The operation is recommended without qualification in all such patients five to eight years of age.

The operation has also been used in some other conditions in combination with lengthening of the soleus with satisfactory results. In resistant club-foot it has proved of value when combined with posterior capsulotomy.

DISCUSSION

Since introducing this operation it is striking that we no longer have spastic children in our clinic with stooped posture, flexed hips and knees, and a gait with the hips in adduction. This procedure has been performed with improvement but sometimes care has not been taken to see that the knees are kept extended until a back-knee position of 5 to 10 degrees develops. If this is not done, part of the benefit of the procedure is sacrificed. Braces, which are constantly removed and reapplied, will not perform this function.

Why does this improvement occur? It is because the child is being protected from the violent effects of decerebrate rigidity produced by the brain lesion, which has overly sensitized the balance (labyrinthine) reflexes to changes in posture, has released the normally useful stretch reflex to produce great power when not needed, and has placed the child in constant fear of falling. I concur with the statement made by a children's psychiatrist that if a child with cerebral palsy is released from fear, the tendo achillis tension and adductor spasm is eliminated in much the same way as that following recession of the gastrocnemius[1]. However, this is not always possible. Recession of the gastrocnemius, when indicated, in children who do not yet walk, allows training of the labyrinthine reflexes in the erect position when fear cannot be overcome in any other way. There is, however, a time when the operation must be done, and that is before training in the erect position is undertaken. Braces are a secondary, not a primary, adjunct in this training.

As has been indicated, gastrocnemius recession is useful in other conditions when combined with lengthening of the soleus; however, the exact place of this

operation in the management of every type of cerebral spastic paralysis is not yet known. At present, the procedure is thought to be preventive, allowing training of the patient without the development of patterns of response to the erect position that are inimical to progressive improvement with age and experience.

It is difficult to change established patterns with this procedure even though the local effect may be achieved. This suggests that the Eggers procedure for lengthening of the hamstrings should be done in older children who have been walking for a time before surgery. It is believed that the same requirements with regard to a back-knee position obtain after the Eggers operation as with recession of the gastrocnemius before any improvement toward a normal pattern can be made; application of casts to the knees for an extended period will be necessary.

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DISCUSSION

Dr. Frederic C. Bost, San Francisco, California: Equinus deformity associated with cerebral palsy and many other conditions is perhaps the most frequently encountered deformity requiring surgical relief. Any method of effecting its relief which gives attention to its cause and offers refinement of technique is therefore worthy of careful consideration. Previous to Dr. Strayer's presentation of the method in 1950, it was customary in our clinic to employ lengthening of the tendo achillis, neurectomy, or a combination of both for equinus deformity in cerebral palsy. The results obtained by these procedures in approximately 200 instances, were considered satisfactory, although it was recognized that a certain number of recurrences of the deformity made necessary the repetition of the operation or the employment of other operations to achieve the desired results.

Following Dr. Strayer's first presentation and after further consultation with him, gastrocnemius recession has been used by me and my associates, almost to the exclusion of other methods. From 1951 through 1955, 177 operations were performed upon 126 patients, most of whom were under the age of ten years. Of these patients, 83 per cent had cerebral palsy. Among the remaining 17 per cent, there were patients with poliomyelitis, spina bifida, as well as other conditions. Ten per cent of the operations were combined with some additional procedure, such as lengthening of the tendo achillis or lengthening or release of the posterior tibialis tendon. But in only one instance was neurectomy employed in distinction to the many we performed in the years before.

While the period of postoperative observation is admittedly limited, the results of these operations have been striking indeed. In 155 operations or 88 per cent of this series, the results are considered excellent or satisfactory. In only four patients has an additional operation for the correction of the equinus deformity been necessary. This is in marked contrast to the former series of operations by lengthening with or without quite so rigid a postoperative program as that advised by Dr. Strayer.

Among the advantages of this operation is the simplicity of its execution, but it is essential that attention be given to Dr. Strayer's description in order that the gastrocnemius may be properly released. This operation is entirely different from that described by Vulpius and as performed by many orthopaedic surgeons in the past. It is not the technical aspect of this operation alone that commends it, but also the thoughtful analysis of the neurophysiological disturbances and the concept of the operation as one which releases an isometric muscular contraction capable of producing deformity.

Our experiences show that early correction of one deformity frequently leads to the amelioration of others, although the need for further operations upon the knee and the adductors has, of course, not been eliminated entirely. There is evidence that they are not nearly so necessary as before so that gastrocnemius recession may be said to be a simple procedure by which the standing and walking positions and the stretch reflex of the patient may be greatly improved. The marked improvement noted in the other deformity of the limbs should be re-emphasized.

Dr. George W. N. Eggers, Galveston, Texas: This is an excellent presentation of experi-

ences in the improvement of equinus deformity in patients with cerebral palsy. In surgery of this type, no one muscle should be treated unless the reaction on the entire extremity is considered. The reflex activity of central and peripheral forces predominate in the interrelationship of the extremity.

The muscular activity of biarticular muscles has long been studied by many associated with surgical achievements; in 1924, Silfverskiöld recorded the changing of the biarticular motor function of muscles to monarticular function. In his work, he transplanted the origins of the rectus femoris, semimembranosus, and biceps, and the heads of origin of the gastrocnemius muscle distally to the femur and tibia, respectively.

In 1912 Stoeffel offered his application of neurectomy of muscles to stop their activity in the cerebral palsy patient by denervation. This method of complete neurectomy did not accomplish the results desired. Therefore, its use is now almost discarded but the application of the method of partial neurectomy has assumed a place of restricted usefulness.

The progressive periods which surgery of the cerebral palsy patient has created in the twentieth century may be said to be (1) elimination of muscular forces; (2) alteration of the same forces; (3) negation of muscular forces; and (4) combination of negative and positive muscular forces.

Elimination of muscular forces was originated when Stoeffel eliminated voluntary muscular motion by neurectomy.

Alteration of muscular forces was achieved by partial neurectomy, tendon transplantation, neurectomy, tenoplasty, rhizotomy, and combination of such procedures; joint fusion was performed and is probably the most important contribution of this period.

Negation of muscular forces was forwarded by Silfverskiöld in 1924 who transplanted the origins of muscles. The thought of depriving muscles of action by negation of motion has always dominated efforts to help the cerebral palsy patient. The results of this were encouraging in the effect on muscular movement. The reaction by reflexes of agonist and antagonist with the resultant forces which the complex reflex patterns of these patients assume became an asset to the person with cerebral palsy.

The combination of negative and positive forces is accomplished in the transplantation of the hamstring insertions in the region of the knee joint and the release of the patellar retinaculum. This procedure negates knee flexion and the positive action of hip extension is emphasized. Thus, we pass to the surgical procedures which negate undesirable forces and reinforce desirable forces.

The improvement of equinus deformity can be accomplished by (1) transplantation or advancement of the heads of the gastrocnemius, (2) partial neurectomy to the soleus, and (3) transplantation of the hamstring muscles and retinaculum release. The importance of this observation is that the mechanism producing equinus deformity can be altered by direct surgical approach and also improved by muscular alterations which are not directly a part of the mechanism. These observations should be studied thoroughly and perhaps we can differentiate the types of equinus deformity for which each method is best suited. By such dynamic analysis progressive improvement of surgery in cerebral palsy patients should be guided.

Management of Brachial-Plexus Injuries (Traction Type)*

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Traction injuries of the brachial plexus have been recognized since the classic descriptions of Duchenne, Erb, and Klumpke. The original cases resulted from birth injuries, presumably from traction forces. During periods of war, penetrating wounds of the brachial plexus have been observed and treated [2]. In recent years, automobile accidents have resulted in an increase in traction or closed injuries to the brachial plexus. This paper reviews our experience with such injuries and offers a few suggestions in their management.

Of 2,500 admissions to the Orthopaedic Surgery Service, Lackland Air Force Hospital, in a twenty-four-month period, sixteen patients had traction injuries to the brachial plexus which resulted in significant permanent neurological deficit. Another group of patients was seen with brief transient paralysis and complete spontaneous recovery. These are not included in this report. Most of the patients in the series were transferred from other hospitals or were patients whose retirement status was being re-evaluated.

MECHANISM OF INJURY

Sufficient force applied to the anatomical elements lying between the neck and arm will produce stretching, tearing, or rupture of structures, but not necessarily in order of their respective position and size. The variable factors are the position of the arm and neck with relation to each other and to the force applied [3]. The upper portion of the plexus may be injured when the arm is drawn backward and adducted or when the shoulder is depressed and the plexus drawn away from the spinal cord by opposite lateral flexion of the neck (Fig. 1). Conversely, if the arm is overhead, the lower portion of the plexus may be drawn from the neck if force is applied to the trunk away from the arm or upon the arm (Fig. 2). Damage may occur at any level of nerve roots, trunks, divisions, or cords of the plexus to produce paralysis depending upon distribution of forces.

CLASSIFICATION OF INJURY

Two approaches are applicable in classifying traction injuries. The older method, based on obstetrical palsy, is the upper (fifth cervical, sixth cervical) or Duchenne-Erb type and the lower (eighth cervical, first thoracic) or Klumpke type. A combined type has been introduced to signify the addition of the seventh cervical-nerve root to either the upper or the lower, or to both, implying a more extensive injury. If the lesion is localized more peripherally in the plexus, Hendry considers it impossible to classify residual paralysis on the basis of nerve-root injury unless the paralysis is equivalent to the loss of a peripheral nerve or a combination of peripheral nerves. Ordinarily the residual involvement is not so clearly defined. As a result he discusses the residual involvement in terms of functional areas, that is, hand, wrist, forearm, elbow, and shoulder, when considering reconstructive measures.

A significant advance in relation to this problem was made by Murphey, Hartung, and Kirklin, when they recognized nerve-root avulsion and demonstrated it by myelography. Myelograms were made of all patients in our series.

* Read at the Annual Meeting of The American Academy of Orthopaedic Surgeons, New York, N. Y., February 1, 1958.

Even though neurological deficit was usually greater than the demonstrable avulsion, the important consideration is that avulsion of a nerve root is an irreversible and irreparable injury. The injuries in this series were classified on the basis of positive myelograms showing the level of involvement, or negative myelograms and the clinical appearance based on neurological deficit. The lesions in the patients without demonstrable avulsion are difficult to classify further since the clinical findings are not always conclusive.

MANAGEMENT OF INJURY

The management of these problems was difficult from the standpoint of diagnosis, prognosis, and time. Most of our patients had concomitant injuries which

FIG. 1

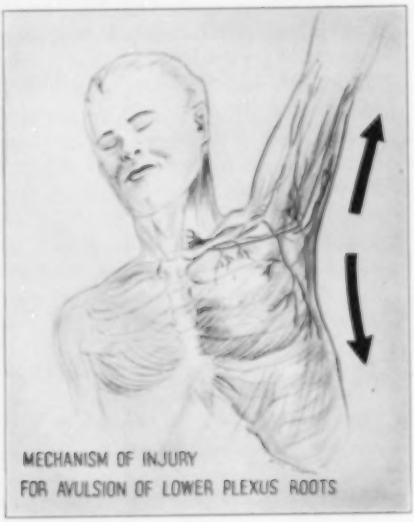

FIG. 2

Fig. 1: Drawing showing relative positions of neck and arm and direction of forces causing injury of the upper portion of the brachial plexus.

Fig. 2: Drawing showing relative positions of neck, arm, and trunk with distribution of forces causing injury of the lower portion of the brachial plexus.

ordinarily required much earlier definitive attention than the brachial-plexus injury. However, the initial neurological examination gave valuable information. Recognition of plexus damage as opposed to a more distal nerve lesion was worth while in itself and served as a guide to future conservative or surgical treatment. The sparing of function of those muscles innervated by the upper or lower portion of the plexus aided in fixing the limits of the lesion. Particularly important was an analysis of the intact sensory functions in relation to the motor loss.

After initial evaluation, support of the involved parts was necessary to reduce further traction forces; either balanced shoulder suspension, shoulder spica, or airplane splint. When there was loss of hand function, dynamic splinting [13], appropriate to the deficit, was applied (Fig. 3). Active and passive exercises were instituted in order to maintain joint mobility and to prevent contractures. This was especially vital in the hand. As soon as the patient's general condition permitted a myelogram was made. Avulsion of brachial-plexus roots was interpreted from the demonstration of the opaque oil passing through the intervertebral foramina into the traumatic diverticula lying extraspinally (Figs. 4, 5, and 6). These pouches were tears or rents in the dura mater left by the avulsed roots. Mendelsohn described the techniques and the application of this diagnostic procedure. If avulsion was evident early reconstructive surgery was considered on

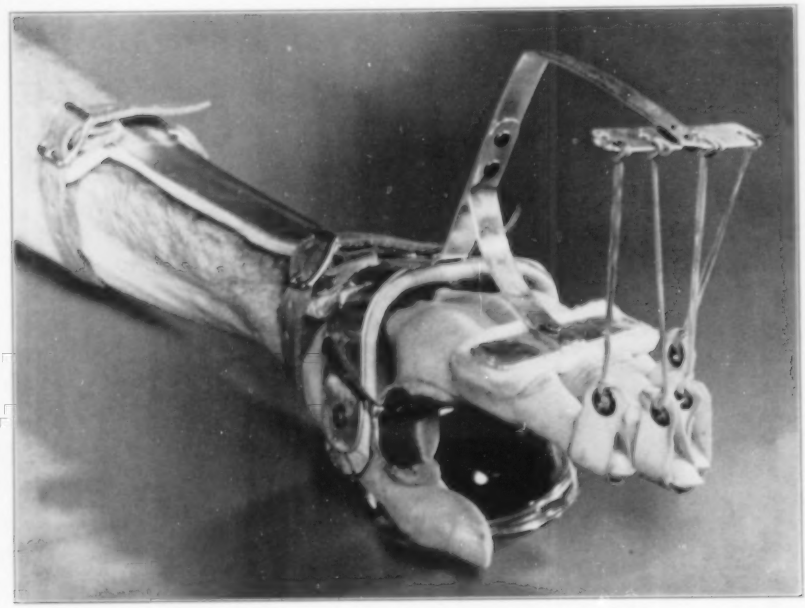

FIG. 3

Dynamic splinting for paralysis of the intrinsic and opponens muscles.

areas of functional loss attributable to the neurological deficit corresponding to the avulsion. In nine of sixteen patients in our group, myelograms were positive (Table I). There were defects of the upper portion of the plexus in three patients, of the lower portion in one, and of the combined type in the remaining five. Brachial-plexus exploration was not indicated in these patients [4, 10].

In patients with negative myelograms, it was thought that the site of injury was within the extraspinal components of the plexus either with or without discontinuity. Supportive measures and physical therapy were then continued and, if there was no significant improvement during a six-month period, exploration of the plexus was considered for prognostic purposes. Neurological repair of such injuries was usually unrewarding[1]. In two of seven patients with negative myelograms and persistent paralysis (Cases 10 and 11) plexus exploration was done; in both extraspinal lesions not amenable to repair were found (Table II). Reconstructive procedures were then done. In three patients (Cases 13, 14, and 15) in whom no brachial-plexus exploration was done, reconstructive measures for the hand were undertaken after a twelve-month period of conservative care. Two patients had residual involvement of the intrinsic muscles of the hand but the degree of impairment did not warrant surgery.

There was only one patient (Case 4, Table I) with residual total paralysis for whom amputation was recommended. All of the other patients had some intact function left in the injured extremity. Partial sensory loss offered no deterrent to reconstructive measures. Either a good shoulder or a good hand was present in patients with avulsion injuries as well as in those with stretch injuries. In order to achieve the basic requirements (a stable shoulder, a flexible elbow, and an opposable thumb and grasp) necessary for restoration of these men to military duty, reconstructive procedures were performed (Table III).

Results of fourteen reconstructive procedures were considered satisfactory with the exception of the patient in Case 9 in whom sensory impairment and fixed contractures precluded successful surgical reconstruction.

TABLE I

BRACHIAL-PLEXUS TRACTION INJURIES WITH POSITIVE MYELOGRAMS

Case	Age (*Years*)	Nerve Roots Involved	Clinical Findings	Level at Which Myelogram Was Positive	Interval Between Injury and Myelogram (*Months*)	Treatment	Remarks
1	20	Seventh and eighth cervical, first thoracic	Paralysis of intrinsic and opponens muscles of the hand, of the finger and wrist flexors; Horner's syndrome	Seventh and eighth cervical, first thoracic	3	Bone block in opposition 7 mos. after injury; wrist flexor tenodesis, 11 mos. after injury	Patient returned to duty as clerk 13 mos. after injury; function of hand satisfactory; also had skull fracture but no residual effects
2	24	Fifth and sixth cervical	Flaccid paralysis in deltoideus, infraspinatus, supraspinatus, trapezius and biceps muscles; sensory loss over deltoideus	Sixth cervical	60	Shoulder arthrodesis recommended but refused	Patient retired for postoperative disc problem, thrombophlebitis, and deafness; shoulder function could have been improved with fusion
3	21	Eighth cervical, first thoracic	Partial paralysis of instrinsic and flexor muscles of the hand; Horner's syndrome	First thoracic	1	Splinting and physical therapy	Patient returned to duty as mechanic 3 mos. after injury, over-all hand function satisfactory; residual weakness of intrinsic muscles
4	27	Fifth, sixth, seventh, and eighth cervical, first thoracic	Flail shoulder and upper extremity; total motor and sensory loss	Sixth and seventh cervical	6	Amputation recommended but refused	Patient was retired; had multiple injuries; no return of function in plexus; re-evaluated 24 mos. later; loss still total

5	35	Seventh and eighth cervical, first thoracic	Sensory loss in ulnar-nerve distribution; finger contractures; paralysis of flexor and intrinsic muscles; Horner's syndrome	Sixth and seventh cervical	3	None	Patient was retired; case re-evaluated 28 mos. after injury; could have been benefitted by bone block and tenodesis if hand mobility had been maintained
6	21	Fifth, sixth, and seventh cervical	Flail shoulder; paralysis of triceps and biceps brachii; weakness of the hand and wrist extensors	Fifth and sixth cervical	2	Shoulder arthrodesis, 3 mos. after injury; elbow flexorplasty, 9 mos. after injury	Patient returned to duty as survival-school instructor, 10 mos. after injury; satisfactory function
7	20	Fifth, sixth, seventh, and eighth cervical, first thoracic	Initial total paralysis; good return of forearm and hand function; causalgia	Fifth and sixth cervical	7	Shoulder arthrodesis, 16 mos. after injury; elbow flexorplasty, 20 mos. after injury	Head injury; no residual effects; unnecessary delay in reconstructive surgery; causalgia regressed slowly; patient returned to duty as armament technician, 24 mos. after injury
8	20	Fifth, sixth, and seventh cervical	Paralysis of deltoideus, supraspinatus, infraspinatus, biceps, and triceps muscles	Sixth and seventh cervical	6	Shoulder arthrodesis, 12 mos. after injury	Patient returned to duty as radio repairman, 16 mos. after injury; satisfactory function
9	38	Seventh and eighth cervical, first thoracic	Contractures of hand; sensory loss; no Horner's syndrome	Seventh and eighth cervical, first thoracic	30	Bone block failed; amputation recommended but refused	Patient retired; unnecessary delays; inadequate maintenance of hand mobility

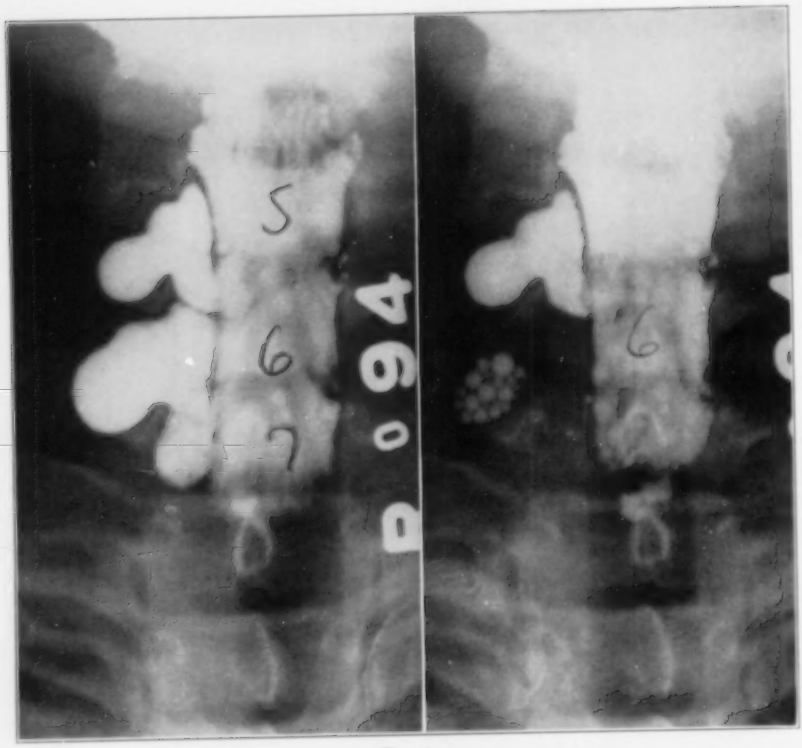

FIG. 4

Case 7. Cervical myelogram demonstrating avulsion of the fifth and sixth cervical-nerve roots on the left. Note the large extraspinal pouches or diverticula in the soft tissue. Clinical diagnosis of root avulsion could not be made.

Shoulder

Fusion was done in four patients with gross instability of the shoulder due to paralysis. Muscle transplantations were not indicated because of concomitant weakness. A partial paralysis of the serratus anterior was not considered a contraindication to fusion provided the lower portion of the muscle was intact. It was felt that shoulder stabilization improves the function of all distal elements in the extremity.

Elbow

Four patients had significant weakness of the biceps and triceps brachii. Two patients (Cases 6 and 7) were unable to flex the elbow and Steindler flexorplasty was performed. This procedure was chosen because good wrist flexors were present. If wrist flexors are not functioning, a posterior bone block of the elbow might be indicated. Flexorplasty was performed in conjunction with shoulder arthrodesis.

Opposition of Thumb

Opponensplasty may be done when feasible. It was done in only one of five patients (Case 14) who were operated on for restoration of opposition of the thumb. The other four patients required bone-block procedures. Two of the patients (Cases 1 and 10) required flexor tenodesis as well. If bone block is necessary and rotation is a problem, a derotation osteotomy of the first metacarpal [3] is helpful. In the patient in whom opponensplasty was performed, the extensor indicis proprius was substituted for the paralyzed first dorsal interosseus.

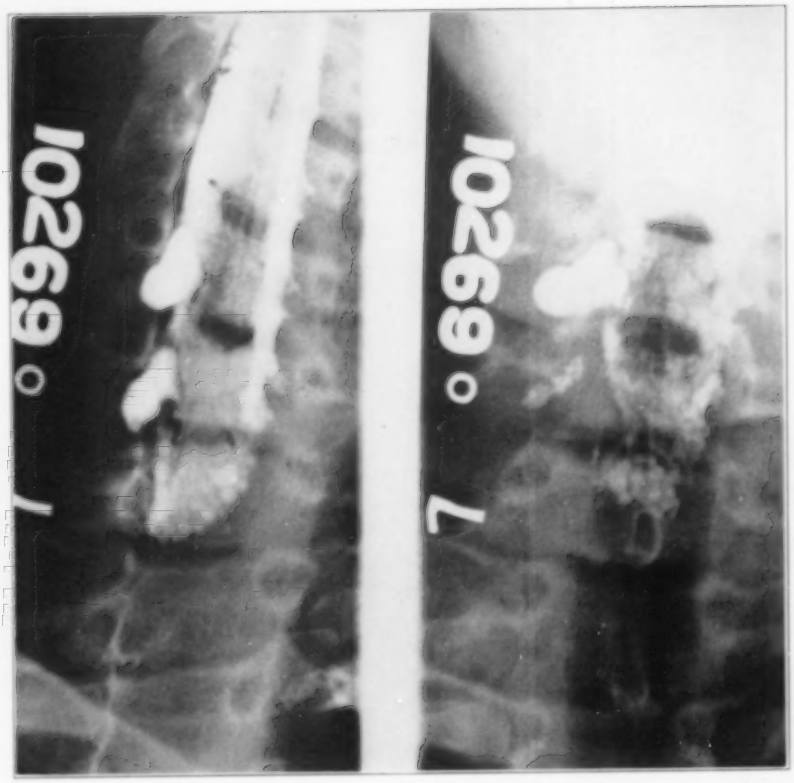

FIG. 5

Case 8. Cervical myelogram showing avulsion of the sixth and seventh cervical-nerve roots on the left with typical pouches filled with pantopaque. Presumptive clinical diagnosis of avulsion could not be made.

Grasp

If flexor power to the fingers and wrist is absent, a satisfactory grasp may still be obtained by flexor tenodesis, although with lack of finger dexterity. Flexor tenodesis (Cases 1 and 10) was performed with satisfactory results (Figs. 7-A and 7-B).

Extension of Thumb and Fingers

In one patient (Case 15) there was a lesion comparable to a radial-nerve injury. Transfer of the wrist flexors to the thumb and finger extensors was done. The result was satisfactory.

RESULTS

Twelve patients returned to military duty in their primary assignments as armament technician, electronic technician, radio repairman, mechanic instructor, survival specialist instructor, laundryman, and clerk. Of the patients who returned to duty five had shown root-avulsion injuries and seven had extraspinal injuries with unresolved paralyses.

Four patients with demonstrable avulsion injuries were retired from military service. One patient (Case 2) was retired for reasons other than his upper brachial-plexus injury. One patient (Case 4) had total functional loss. Amputation was recommended and refused. One patient (Case 5), whose function might have been improved with early reconstructive surgery, was not seen until twenty-eight

TABLE II

BRACHIAL-PLEXUS TRACTION INJURIES WITH NEGATIVE MYELOGRAMS

Case	Age (*Years*)	Nerve Roots Involved	Clinical Findings	Myelogram	Interval Between Injury and Myelogram (*Months*)	Treatment	Remarks
10	23	Seventh and eighth cervical, first thoracic	Paralysis of intrinsic muscles of hand, of finger and wrist flexors; no Horner's syndrome	Negative	8	Exploration of brachial plexus, 9 mos. after injury; repair non-union of clavicle; bone block in opposition, 26 mos. after injury; wrist flexor tenodesis, 31 mos. after injury	Patient returned to duty as jet-engine mechanic instructor, 33 mos. after injury; handled tools with good strength; delayed by brachial-plexus exploration and non-union of clavicle
11	28	Fifth and sixth cervical	Paralysis of deltoideus, supraspinatus, and infraspinatus muscles; serratus anterior and rhomboideus major and minor intact; weakness of trapezius and biceps brachii; sensory loss over deltoideus	Negative	5	Exploration of brachial plexus 6 mos. after injury; shoulder arthrodesis, 26 mos. after injury	Patient returned to duty as senior clerk, 30 mos. after injury; function satisfactory
12	18	Seventh and eighth cervical, first thoracic	Paralysis of intrinsic muscles of hand; weakness of finger and wrist extensors	Negative	5	Support and physical therapy; good return	Patient returned to duty as jet-engine mechanic, 6 mos. after injury; function of left hand satisfactory but without dexterity

13	21	Fifth, sixth, seventh, and eighth cervical, first thoracic	Initial total paralysis; residual palsy of opponens; paralysis of finger and wrist flexors; deformity and anaesthesia of index finger	Negative	3	Ray amputation of index finger, 11 mos. after injury; bone block in opposition, 15 mos. after injury	Patient returned to duty as electrician, 18 mos. after injury; satisfactory function of left hand; patient seen late
14	28	Eighth cervical, first thoracic	Paralysis of intrinsic and opponens muscles of hand; finger flexors weak	Negative		Craniotomy, 3 wks. after injury; palmaris longus transfer to short thumb extensor; indicis proprius transfer to first dorsal interosseus, 12 mos. after injury	Patient returned to duty as laundryman, 14 mos. after injury; hand function satisfactory; subdural hematoma; no residual effects
15	22	Sixth, seventh, and eighth cervical	Paralysis of finger and wrist extensors; posterior cord of the plexus involved	Negative	4	Radial and ulnar wrist flexor transfers to thumb and finger extensors, 12 mos. after injury	Patient returned to duty as electronic technician, 14 mos. after injury; function satisfactory; also had compound fracture of tibia which healed
16	20	Eighth cervical, first thoracic	Paralysis of intrinsic muscles of hand, of wrist flexors; sensory loss of ulnar nerve; Horner's syndrome	Negative	3	Splinting and physical therapy; good return of motor and sensory components	Patient returned to duty as clerk, 4 mos. after injury; function satisfactory without surgery

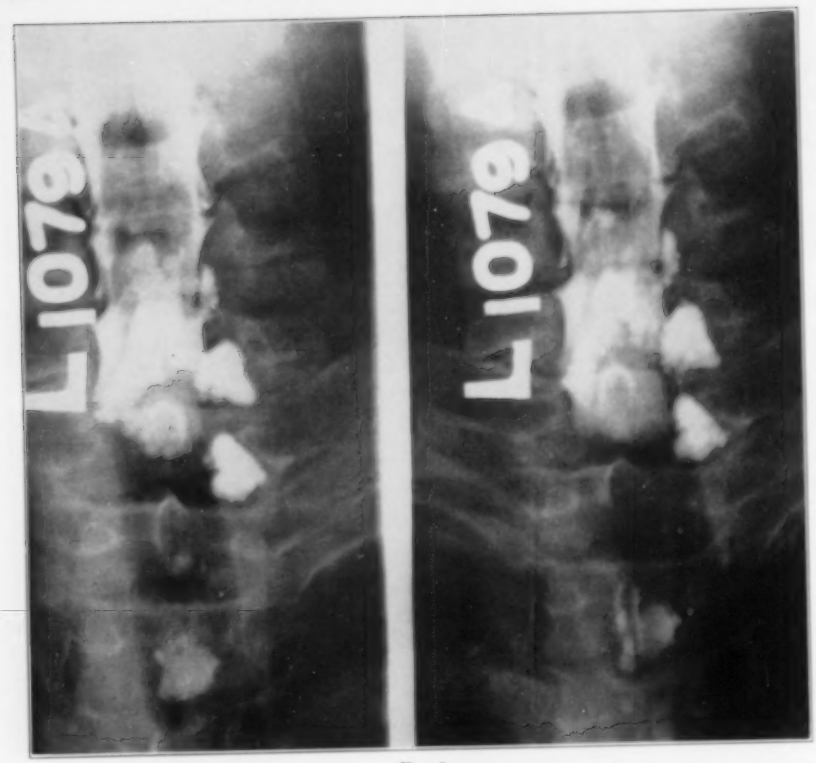

FIG. 6

Case 9. Cervical myelogram of a combined type of brachial-plexus injury. The traumatic meningoceles are demonstrated at the level of the seventh and eighth cervical and first thoracic-nerve roots, on the right. The pantopaque study was made thirty months after injury.

months after injury. One patient (Case 9) was seen thirty months after avulsion of the lower portion of the plexus. He had sensory loss and contractures of the hand. Reconstruction, done in place of amputation, was unsuccessful.

COMMENT

The patients in this small series did not have ideal management. This was

FIG. 7-A

FIG. 7-B

Case 10. Result of bone block in opposition and wrist flexor tenodesis. Patient had exploration of brachial plexus with evidence of irreparable damage. Preoperatively there was virtually complete loss of finger and wrist flexor function; there was no opposition of the thumb or appositional movements. The patient returned to work as a mechanic.

TABLE III

RECONSTRUCTIVE PROCEDURES

Operation	Case	Result
Shoulder fusion	6	Satisfactory
	7	Satisfactory
	8	Satisfactory
	11	Satisfactory
Flexorplasty	6	Satisfactory
	7	Satisfactory
Bone block in opposition	1	Satisfactory
	9	Unsatisfactory
	10	Satisfactory
	13	Satisfactory
Flexor tenodesis	1	Satisfactory
	10	Satisfactory
Opponensplasty	14	Satisfactory
Wrist flexors for finger extensors	15	Satisfactory

particularly true in the patients with root avulsion, in many of whom earlier myelographic studies and reconstructive surgery could have been done. Delineation of the extent and site of injury and evaluation of reversibility, when possible, can permit institution of measures which would effectively shorten morbidity.

In our opinion only total plexus avulsion presents an unsalvageable problem which may require amputation. In partial plexus injuries, with or without avulsion, acceptable function may be restored, with proper management.

SUMMARY

Brachial-plexus injuries from violent traction may result in permanent intraneural damage. This damage may occur within the plexus proper, that is, trunks, divisions, or cords or it may occur by avulsion of the nerve roots forming the plexus. Clinically, these injuries result in a variety of neurological deficits but roughly follow the pattern of obstetrical palsy. They may be further classified on the basis of myelographic findings. The deficit, with the exception of total and permanent plexus loss, is amenable to reconstructive surgery. Reconstructive procedures should aim at shoulder stability, elbow flexibility, thumb opposition, and hand grasp. A definite plan of treatment must be instituted. The utilization of diagnostic myelography and the early performance of surgery, when indicated, is urged to shorten morbidity and return the patient to work as soon as possible.

NOTE: The authors gratefully acknowledge the assistance and advice rendered by Major Robert A. Mendelsohn, Chief of Neurosurgery Service, and Major James M. Keegan, Chief of Radiology Service, Lackland Air Force Hospital, Texas, in the preparation of this manuscript.

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DISCUSSION

Dr. Leonard T. Peterson, Washington, D. C.: Brachial-plexus injury has a poor prognosis unless spontaneous recovery becomes apparent within three months. Operative repair may be of some value in plexus injuries due to missiles or stabbing, in contrast to traction paralyses where surgery is of little benefit. Exploration of the plexus is of value only in case an element is found severed. Gross inspection of a neuroma in continuity cannot determine the possible recovery of function, and in these cases, resection of the neuroma and repair is not justified.

Neurolysis to remove extraneural scar has little or no effect on recovery of nerve function. Nothing is to be gained by surgical exploration in traction paralysis where the damage is due to avulsion of roots or to intraneural scar. Lower plexus injuries involving the distal muscles of the hand offer a very poor prognosis for recovery.

The volume *Peripheral Nerve Regeneration. A Follow-up Study of 3,656 World War II Injuries* includes 117 lesions of the brachial plexus. The only cases included were those which met the following criteria: were available for follow-up, had adequate records, failed to show recovery within two months, and were surgically explored. Only five cases in this series of 117 brachial-plexus lesions were due to stretch paralysis, since most were obviously due to missiles in wartime. Following surgery none showed recovery below the shoulder. Four of the five accepted amputation and were pleased with the choice.

The authors have discussed an interesting variety of reconstructive procedures with satisfactory results. Physical therapy is important until maximum recovery has been attained, but should not be continued indefinitely in a hopeless extremity. The probable degree of recovery should be apparent in about six months, and tendon transfer, when indicated, should be performed soon thereafter.

In summary, the prognosis is very grave in traction paralysis of the brachial plexus where there is not significant improvement in three months. In these injuries surgery is of little or no value. In complete lesions, amputation is ultimately required.

Observations of Neuropathic (Charcot) Joints Occurring in Diabetes Mellitus*

BY JULIAN E. JACOBS, M.D., CHARLOTTE, NORTH CAROLINA

Charcot joints and painless neuropathic ulcers of the lower extremity, although often stated to occur commonly in tabes dorsalis and syringomyelia, are not uncommon in diabetes mellitus [20].

The extreme care accorded the feet in patients with diabetes stems primarily from frequent infections following inadequate foot care [11]. The importance of peripheral nerve disease as a cause of night pains, loss of certain sensations, and occasional trophic ulcers has not been stressed.

In 1936, Jordan [12] reported a case with typical Charcot joint findings in a patient with poorly controlled diabetes. Bailey and Root, in 1947, reported seventeen cases of painless destruction of the tarsus. Rundles, Foster and Bassett, Lister and Maudsley, Beidleman and Duncan, Sheppe, and others [22, 24] have added case reports with their observations of the cause of the disease.

As late as 1951, Parsons and Norton reported two cases in which symptoms appeared to be arrested after lumbar sympathectomy. The neurological examination showed absent patellar and Achilles tendon reflexes, stocking anaesthesia, and tender nerve trunks in the thighs.

Jordan [13], in 1953, felt that secondary bone changes resulting from nervous-system involvement might be due to a nutritional deficiency; others blamed impaired circulation.

The monograph by Rundles on diabetic neuropathy referred to one patient with trophic changes in the tarsometatarsal joint.

The patients with arthropathy all demonstrated evidence of peripheral neuritis and a history of poorly controlled diabetes. Involvement of the ankle joint has been reported by Foster and Bassett, Muri, Knutsson, and Cram [5]. Out Case 3 added to these reports makes a total of five instances of ankle involvement in the world literature up to 1956. De Takats, Shore, and Spear each briefly reported a patient with involvement of the knee joint. Wilson, McIntyre, and Albertson, in a detailed case report of pedal involvement, felt that the joint changes were due to pathological neurotrophy. More recent reports by Antes, Martin, Cram [6], Lippman and Grow, and Bolen substantiate the primary neurotrophic involvement. Many writers have noticed that the circulatory status of the involved lower extremity was usually good. Perforating ulcers without gross infection or gangrene further substantiate observations that adequate circulation exists.

The clinical manifestations of neuropathic diabetes are characterized by dissociation of sensations such as hyperaesthesia, hypaesthesia, or loss of the sensations of vibration, position, temperature, or touch in varying degrees at different times. Ankle reflexes are usually absent or diminished, and knee reflexes are less frequently involved. There is weakness of the motor tract, particularly of the hands, quadriceps, and the dorsiflexors of the ankle. This motor weakness has been stressed by Cram [6] and Rundles. The early signs are painless thickening about the fore part of the foot or ankle, occasionally associated with a history of trauma. Rapidly progressive shortening and thickening of the fore part of the foot or ankle can occur. Trophic ulcers below the heads of the first, second, third, or fourth metatarsophalangeal joints may be noted without gross infection. Pulsations in the foot are usually present even if roentgenograms show marked arteriosclerosis (Fig. 2-A).

*Read at the Annual Meeting of The American Academy of Orthopaedic Surgeons, Chicago, Illinois, January 28, 1957.

FIG. 1-A

Case 1. Pathological fracture of the second metatarsal of the right foot. Fragmentation of the fifth metatarsal head can be seen.

FIG. 1-B

Seven weeks later, there is added fragmentation at the base of the first metatarsal.

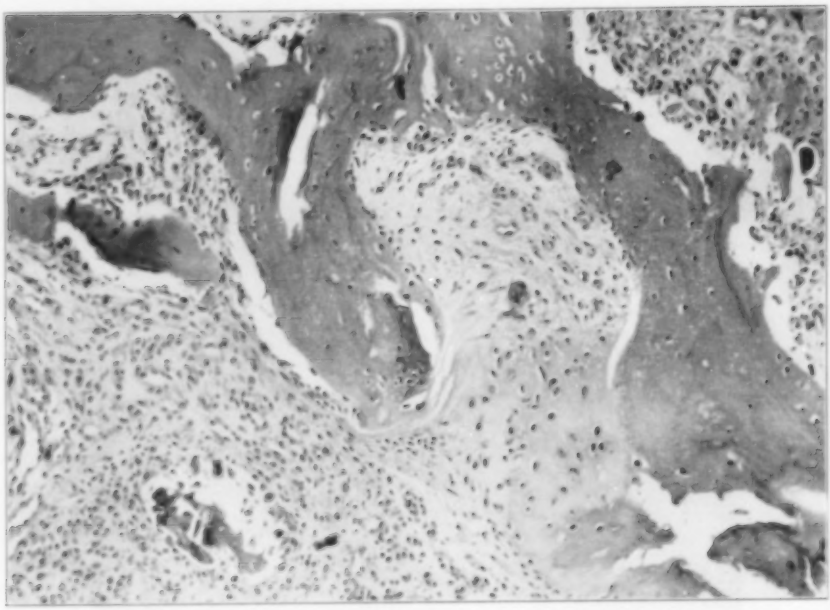

FIG. 1-C

There was no evidence of tumor or osteomyelitis. Routine cultures were negative.

Early roentgenograms show fragmentation of the articular cartilage and the adjoining bone. The small islets of fuzzy bone growing in the synovial membrane are the most reliable pathognomonic features of the neurogenic arthropathy [14]. The associated atrophy of the phalanges and metatarsals, particularly the distal portion of the fifth metatarsal, was noted early in our two cases (Fig. 1-A) even before the fragmentation at the proximal portion of the metatarsals in Case 2.

Hodgson, Pugh, and Young reviewed the clinical findings of sixty-one patients whose roentgenograms showed evidence of neuropathic joints. All patients had an acute or chronic inflammatory process of the soft tissue in the region of the involved bones, and all but six had a definite ulcer. Twenty-one of these patients had diabetes. These investigators concluded that there was a definite relationship between the duration and the extent of infection and the progression of the disease and bone destruction.

The routine laboratory procedures for a patient with diabetes were carried out, but the presence of elevated spinal-fluid protein was noted. A relatively low cell count was noted similar to that seen in radiculoneuritis (Guillain-Barré syndrome) in which there are anatomical changes in the posterior nerve roots and posterior nerve-root ganglia [18].

Lesions of the nervous system, as reported by Schweiger, Williamson, and Muri showed degeneration of the intramedullary fibers of the posterior nerve roots and sclerosis of the posterior columns, secondary to extramedullary lesions similar to those in tabes dorsalis. Martin [20] demonstrated varying degrees of myelin degeneration of the axis cylinders without any signs of endoneural or perineural fibrosis or degenerative disease of the vasa nervorum.

The fibers of the sympathetic nervous system are frequently functionless. De Takats showed that fibers that conduct pain slowly (non-myelinated C fibers), operating at one to two meters per second, remain intact; myelinated fibers that rapidly conduct pain, operating at thirty to eighty meters per second, are affected by sensory defects.

The bone lesions are typically those seen in the neuropathic arthropathy of

FIG. 1-D

Healing of lesions has occurred approximately six months after the patient's first visit. Weight-bearing with a cane is possible.

FIG. 1-E

Eleven months after surgery, the patient is walking.

FIG. 1-F

Roentgenograms showing early destruction of the fifth metatarsal head.

syphilis and syringomyelia. There is complete loss of bone structure with numerous spicules of bone scattered throughout the area of involvement. These undergo various stages of absorption with minimal attempts at regeneration. There is some attempt at periosteal new-bone formation.

CASE 1. C.W.W., a housewife, sixty-eight years old, had had mild neurotrophic arthropathy of the fore part of the foot which had since healed. She had had diabetes for fourteen years, but it was well controlled. When first seen on July 18, 1946, a diagnosis was made of pathological fracture at the base of the second metatarsal of the right foot. This had been painful and slightly swollen, but not red, for one month. There was no history of injury. Treatment consisted in walking with crutches and elevation of the extremity; biopsy was advised.

The patient was taking thirty-five units of protamine zinc insulin each day. Her blood sugar was 112 milligrams per 100 milliliters. A Wassermann test was negative. The patient deferred hospitalization. On September 7, 1946, seven weeks after the first roentgenogram (Fig. 1-A), another roentgenogram showed added fragmentation of the first metatarsal at its base (Fig. 1-B). The patient was still using crutches.

On October 10, 1946, urinalysis revealed the following. The specific gravity was 1.026; pH, 5.5; and epithelial cells, +. There was a slight trace of albumin, and no acetone. Sugar was +++, and white blood cells were 3 to 4. Wassermann test was negative.

On October 18, 1946, three months after her first office visit, the patient was admitted to the hospital for study and biopsy. Her general physical condition was excellent. Both lower extremities had excellent pulsations; however, both ankle reflexes were absent. Knee reflexes were diminished bilaterally. Indefinite hypaesthesia from knees to toes was noted. Vibratory sense was absent in both ankles and feet, but position sense was intact.

On October 19, 1946, red blood cell count was 3,660,000, and the white blood cell count was 6,750. Hemoglobin was 11.2 grams per 100 milliliters, or 77 per cent of normal. In the differential count there were 65 per cent polymorphonuclear neutrophils, 34 per cent lymphocytes; and 1 per cent eosinophils. Her blood sugar on fasting was 111 milligrams per 100 milliliters of whole blood.

Urinalysis on October 24 revealed a specific gravity of 1.015, pH of 5.0, 15 to 20 white blood cells, and a few epithelial cells. Sugar and acetone were absent, and only a slight trace of albumin was present.

On October 22, 1946, biopsy under tourniquet disclosed vascular porotic bone at the base of first metatarsal. We still labored under the mistaken diagnosis of low-grade osteomyelitis, and continued to administer antibiotics. Roentgen therapy was administered in

FIG. 1-G

Over nine years from her first visit, roentgenograms show the fore part of the right foot healed.

FIG. 1-H

The fore part of the left foot is normal.

FIG. 2-A

Case 2. Trophic changes of the fifth metatarsophalangeal joint are seen.

doses of 1200 r. The patient was discharged on crutches, with directions to continue her thirty-five units of insulin daily, liver injections, and vitamin-B complex capsules. The wound had healed satisfactorily.

Histological examination of the excised bone tissue showed many fragmented and necrotic spicules surrounded by cellular connective tissue in which closely packed small blood vessels with prominent endothelial lining cells were a conspicuous feature. Rows of prominent osteoblasts and narrow osteoid seams were found around some of the viable bone spicules. There was no evidence of tumor or osteomyelitis. Routine cultures were negative (Fig. 1-C).

On January 9, 1947, new roentgenograms showed improvement so that by February 12 the patient was able to walk with a cane without discomfort (Fig. 1-D).

Eleven months after biopsy, roentgenograms (Fig. 1-E) showed complete reconstruction of the former lesions. In September 1949 another roentgenogram still showed good bone architecture. The patient was not seen until August 1952 when she complained of aching knees. The diabetes was well controlled and an incidental roentgenogram of the fore part of the foot showed only early destruction of the head of the fifth metatarsal (Fig. 1-F). Limited weight-bearing with a cane was again advised. On August 12, 1955, when the patient was next seen, she was taking only five units of insulin a day, had no complaints, and roentgenograms revealed a completely normal fore part of the right foot; her left foot was also normal (Figs. 1-G and 1-H).

On September 19, 1956, we noted for the first time, after observation of ten years, that the patient, now seventy-eight years old, had ulcers over the second and third toes. Roentgenograms still revealed nothing, and showed no recurrence of arthropathy. On September 27, amputation of the second and third toes at the metatarsophalangeal joint was performed. She was discharged on October 8, the stumps having healed.

The case report should include that the patient had been given chloramphenicol by her family physician for as long as a month at a time, in addition to the vitamin-B complex capsules.

CASE 2. W. G. F., a policeman, fifty-seven years old, had had diabetes for twenty years. He was seen December 30, 1953, with a diagnosis of draining ulcer on the plantar surface of the first metatarsophalangeal joint of the left foot, of seven months' duration. Roentgenograms (Fig. 2-A) showed non-symptomatic trophic changes in the area of the fifth metatarsophalangeal joint, no bone changes about the first metatarsophalangeal joint, and calcified blood vessels of the left foot.

The patient gave a history of having been burned with a heating pad when he was in a hospital in October 1952 for a sprain of his left ankle. There had been drainage ever

FIG. 2-B

A little over one year from the first office visit, diabetes was controlled. There was almost complete disintegration of the fore part of the foot.

FIG. 2-C

The fore part of the opposite foot is normal.

FIG. 2-D

One year and seven months from the first visit, there are no ulcers. The patient is walking.

FIG. 2-E

Two years and seven months from the first visit, there is persistent disintegration of bone.

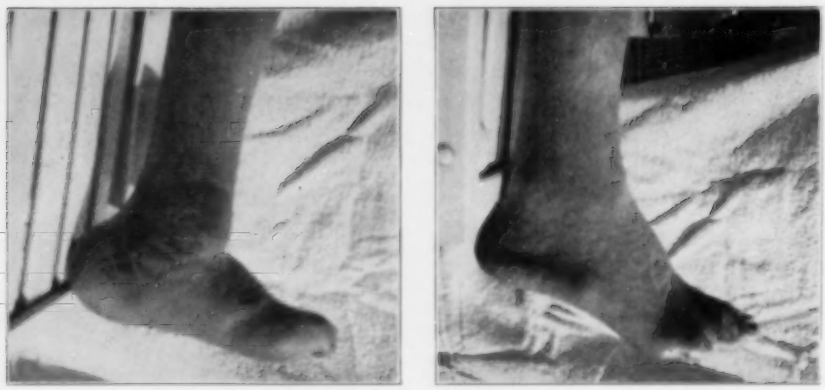

FIG. 2-F

Photographs made of both feet at the same time as the roentgenograms in Fig. 2-E.

since from the sole of the foot. The patient was walking in a cut-out shoe, and taking seventy units of protamine zinc insulin daily. A diagnosis of early arthropathy was made. On admission to the hospital on January 1, 1954, the patient was placed on a program to control the diabetes and on a weight-reduction diet. The application of heat (dry and wet), elevation of the extremity, antibiotics, and vitamin-B complex capsules accomplished healing of the ulcer. Ankle reflexes were absent, but knee reflexes were active. Definite progressive hypaesthesia was noted from knee to toe bilaterally. Vibratory sense was absent at both ankles. Position sense was good. Fasting blood sugar was 116 milligrams per 100 milliliters of whole blood. The results from the rest of the laboratory studies were within normal limits; Wassermann test was negative. Roentgenograms showed no change since December 1953.

The patient was able to be fairly active for one year by taking fifty units of insulin daily and by wearing especially fitted orthopaedic shoes. The diabetes and weight reduction were well controlled by his family physician. However, for several days before his readmission on January 23, 1955, cellulitis developed on the dorsum of the fore part of the left foot and leg. He was readmitted and had the same routine care; he had no unusual laboratory findings. He was discharged on February 22, 1955, with his pulsations still good, and a small amount of serous drainage from the area of the old trophic ulcer. We noted that the fore part of the foot was one-fourth inch thicker but one inch shorter than the year before. In this interval almost complete disintegration of the fore part of the foot had occurred roentgenographically (Fig. 2-B). The patient was discharged on crutches but could touch the floor with his left foot in a slipper.

When re-examined on June 24, 1955, the patient still showed some thickening and shortening of the fore part of the left foot, but was walking with a cane. He was taking forty units of protamine zinc insulin daily (Fig. 2-D). There was no ulcer.

The last examination on June 24, 1956, two years and seven months after the first visit, showed the patient's status unchanged. There was no drainage or cellulitis. He had reduced the insulin intake to twenty units each day. New roentgenograms (Fig. 2-E) showed the persistent disintegration of bone elements, and photographs of the fore part of the feet were made for record (Fig. 2-F).

CASE 3. J. N., a thirty-year-old unemployed man, had had diabetes for thirteen years. He was first seen on January 3, 1952, with a diagnosis of pathological fracture of the right ankle and neurological disorder. Roentgenograms made on February 18, 1952, (Fig. 3-A) showed marked disintegration of the right ankle joint. This was fairly painless, but the patient walked into the examining room with marked inversion of the ankle. He was taking thirty units of protamine zinc insulin daily. Because of a painless prominence on the opposite heel, a roentgenogram (Fig. 3-B) was made for record. There was no history of trauma to the left ankle. A roentgenogram of the site of a previous sprain of the right ankle made on June 30, 1951, was normal (Fig. 3-C). The patient gave a history of progressive painless deformity with swelling of his right ankle since November 1951 (five months after the normal roentgenogram of his right ankle). There was no history of trauma since.

On admission to the hospital on May 2, 1952, the patient added that for five to six years he had noted sharp shooting pains down the backs of both legs with claudication on ambulation. Repeated superficial skin ulcers occurred over both legs but healed. There was no family history of diabetes.

FIG. 3-A

Case 3. Although there is marked disintegration of the right ankle, it is painless. The patient is walking.

FIG. 3-B

Roentgenogram made of the opposite heel.

FIG. 3-C

Roentgenogram made of the right ankle eight months earlier, at the time of a sprain, is normal.

The patient's general physical condition on examination was excellent. His blood pressure was 124 systolic and 76 diastolic. His pulse rate was 76 per minute and his respirations, 18. The patient appeared undernourished and demonstrated hypo-active knee and ankle reflexes. There was progressive bilateral hypaesthesia from knee to toe, but vibratory, position, and light-touch sensations remained intact. The pulsations were good. Fasting blood sugar on admission was 263 milligrams per 100 milliliters of whole blood. This imbalance was brought under control with forty units of protamine zinc insulin daily.

On May 2, 1952, blood studies revealed the following: red blood cells, 4,110,000; white blood cells, 9,200; hemoglobin, 11.6 grams per 100 milliliters or 74 per cent of normal; non-protein nitrogen, thirty-three milligrams per 100 milliliters; polymorphonuclear neutrophils, 86 per cent; lymphocytes, 22 per cent; and eosinophils, 2 per cent. Wassermann test was negative.

His basal metabolic rate was —0 per cent. An electrocardiogram was normal, and his chest was clear.

On May 6, 1952, cerebrospinal-fluid studies showed that the fluid was clear; there were no mononuclear cells. There was a trace of globulin, 86 milligrams of protein, 159 milligrams of glucose, and 726 milligrams of chlorides per 100 milliliters of fluid. The result of the mastic test for cerebrospinal syphilis was 110,000,000; Wassermann test was negative. The carbon dioxide combining power was 55 volumes per cent.

Results of other studies were: concentration of serum sodium was 135 milliequivalents per liter; serum calcium, 10.6 milligrams per 100 milliliters; and serum phosphorus, 3.8 milligrams per 100 milliliters. In the quantitative measurement of bilirubin in serum, total bilirubin was 0.4 milligrams per 100 milliliters; direct bilirubin, 0.2 milligrams; and indirect bilirubin, 0.2 milligrams per 100 milliliters.

Total serum protein was 6.4 grams per 100 milliliters: serum albumin was 4.3 grams per 100 milliliters and serum globulin was 2.1 grams per 100 milliliters.

Alkaline phosphatase was 4.9 Bodansky units.

There was no dye reaction in the phenolsulphonphthalein test on a urine specimen tested forty-five minutes after intravenous injection of phenolsulphonphthalein.

On May 13, 1952, a below-the-knee amputation of the right leg was performed under tourniquet. An uneventful convalescence followed and the patient was discharged on June 4, 1952. On August 15, 1952, he was fitted with a prosthesis and a note was made that the diabetes was under control. On April 1, 1954, a new prosthesis was applied because he had been walking a lot. The diabetes was under control.

On February 21, 1955, the patient died suddenly of coronary thrombosis. He had been active with his below-the-knee stump for two and one-half years.

DISCUSSION

Three patients with diabetic neuropathic arthropathy treated in ten years in a moderately sized orthopaedic clinic should alert us to this entity. These cases bring the total cases in the world literature to forty-five (1956). Our first inclination to call these lesions osteomyelitis or tumor was shown in Case 1. Even the roentgenologists helped to confuse us in Cases 1 and 2. Ruling out syphilis, syringomyelia, and the neural form of leprosy should be routine. The presence of a trophic ulcer in a patient with diabetes should make one suspect early arthropathy and demand frequent roentgenographic examinations. Certainly early walking with crutches and later limited weight-bearing kept the patients in Cases 1 and 2 ambulatory until the time of writing, ten years and three years, respectively. Sponge-rubber arch supports in Case 1 and a specially molded orthopaedic shoe in Case 2 made walking easier for the patients. We know that a good prosthesis for a patient with a below-the-knee amputation will serve well without skin breakdown. The patient in Case 3 was active for two and one-half years.

Why did the lesion in Case 1 return to normal and those in Cases 2 and 3 rapidly disintegrate? Charcot's original term *trophic* still applies, and inadequate sensation, motor instability, laxity of tendons and ligaments, and hyperaemia of the synovial membrane [31], as well as repeated small traumata [8], contribute to fracture and subluxation around a joint. McMurray, in 1950, reported a patient who from birth had shown insensitivity to pain and had a deformity of the left ankle suggesting a Charcot joint.

If the posterior columns [27, 31] and the extramedullary posterior-root ganglia [20] are involved, what factors reversed these changes in Case 1? The patient's diabetic condition was controlled before and after arthropathy. Toxins, if any, could not be demonstrated. Vitamin deficiency was possible and was treated with liver injections and vitamin-B complex capsules. She had received repeated series of chloramphenicol therapy (250 milligrams four times a day for one month or more). She also had roentgen therapy, which may have affected the local lesion, but hardly affected the neuropathy. Eisenstadt and Eggers, in describing arthritis mutilans, a pathological condition which is still not understood, described a similar type of lesion at the metatarsophalangeal joints and indicated that roentgen therapy seemed to have improved the feet, subjectively and objectively. The patient's sturdy orthopaedic shoes and sponge-rubber arch supports were merely adjuncts, as suggested by Marble.

The same careful follow-up study was made in Case 2, and the patient's foot literally disintegrated before our eyes. An additional factor could have been toxins from an ulcer during the early phase of treatment. No ulcer was present in Case 3 and the patient's ankle disintegrated under observation. The first two patients had well controlled diabetes prior to their examinations; however, in Case 3 the treatment remained difficult. Although the diabetes was adequately controlled, the patient could do more walking than the others on his trouble-free prosthesis.

The following points are important to consider for treatment: (1) diabetes should be adequately controlled, (2) vitamin-B complex capsules or liver-injection therapy or both should be prescribed, (3) weight-bearing during the early stages

of foot lesions should be avoided, (4) ulcers should be treated, (5) amputation should be done if necessary, and (6) proper orthopaedic appliances such as shoes, supports, or walking casts should be used for a while [1, 28]. Lippman and Grow felt that vitamin-B complex, vitamin B_{12}, and ACTH were beneficial.

SUMMARY

Although cases of neuropathic arthropathy are rare, with only forty-five cases reported in the world literature until 1956, our experience with three patients in ten years prompted us to invite the attention of orthopaedic surgeons to the lesions. I have stressed certain early roentgenographic diagnostic points and reported the only case in the literature, to my knowledge, in which the patient had complete reconstruction of an arthropathic joint, with a ten-year follow-up study. I urge physicians to make early and repeated roentgenograms of feet and ankles of any patient with diabetes. When it is necessary to amputate, a satisfactory and functional stump often remains.

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DISCUSSION

Dr. James P. Miller, Baltimore, Maryland: This report by Dr. Jacobs of three additional cases of diabetic neuropathy certainly requires no further comment from me. There are, however, two points to which I would like to draw your attention. In the first case, the patient had well controlled diabetes and there was no evidence of infection or ulceration; her circulation was considered adequate. Under supportive measures, her lesion healed completely during a ten-year follow-up study. Insofar as I know, this was the first reported case of a neurotrophic joint healing. In spite of the absent ankle reflexes and vibratory sense, and the diminished knee reflexes, I am suspicious of the original diagnosis.

The second point to emphasize is the importance of ruling out associated peripheral neuritis and infection as contributory to the deformity in most cases. Most of the patients in the reported cases have had evidence of acute or chronic inflammatory conditions and many have had associated peripheral neuritis. These conditions can certainly confuse one in the establishment of a diagnosis of a true neurotrophic joint.

Dr. Robert Cram, Philadelphia, Pennsylvania: It is a pleasure to discuss a subject which is increasing in importance and in which there are still many unanswered questions.

In the days before insulin the patient died before a neuropathy or arthropathy could develop and, therefore, most of our literature is contemporary. In our series of neuropathies, there were no patients with well controlled diabetes. A patient who will not cooperate or in whom an intercurrent infection develops or who has not been on an adequate regimen is predisposed to the development of an arthropathy secondary to a neuropathy. The neurological manifestations improve, but are not necessarily cured, when the diabetes can be controlled by diet and insulin. This supported the view of Dr. Joslin that the various vitamin deficiencies were not important in the pathogenesis of the neuropathy. Many of the older diets for patients with diabetes were deficient in vitamins and many have contributed to the symptoms to a very mild degree.

Since the arthropathy is always secondary to a neuropathy, let us consider this phenomenon in more detail. There are three important clinical types:

1. The hyperirritability of peripheral nerves during a hyperglycemic attack is of no clinical importance.

2. The circulatory type is characterized by peripheral paraesthesia, hyporeflexia, hyperaesthesia, and intermittent claudication with absent pulses. This type presents few orthopaedic problems.

3. The true diabetic neuropathy, although the least well known type, is most interesting and is important diagnostically. It gives the vague clinical picture of either weakness, radiating pain, particularly at night, paralysis, anaesthesia, or bladder and bowel dysfunction. A neuropathic arthropathy may follow. The disease is in the spinal cord, not in the peripheral nerves. Loss of vibratory or position sense appears to be caused by the specific lesion that is responsible for the development of a neuropathic joint. One cannot give an explanation for this type of ankle and tarsal involvement as one can for syphilis.

Emphasis should be given to King's observation that there is a pathognomonic roentgenographic feature of a neuropathic joint. In addition to the well known fragmentation of the bone, small fuzzy islets of new bone in the synovial membrane allow a specific diagnosis to be made both roentgenographically and microscopically.

No discussion of diabetic arthropathy is complete without reference to Eloesser's work in which he showed that two factors are necessary for the development of a neuropathic joint. A joint that is denervated will not disintegrate unless trauma is subsequently applied to it. The trauma is often slight but may be caused by a definite twist or a mild fracture with all its medicolegal ramifications.

A laboratory aid in the confirmation of the diagnosis is the cerebrospinal fluid protein elevation to between fifty and 100 milligrams per 100 milliliters. This occurs in 80 per cent of patients.

The most important point in Dr. Jacobs' excellent paper is the patient with a complete reconstruction of a destroyed joint. Six months ago when I was confronted with this foot showing fragmentation of the talonavicular joint, in an unreported patient, thirty-five years of age, I had to give a very gloomy prognosis advising a change of occupation and a palliative rigid foot support. The diabetes had been out of control for about three months due to an acute soft-tissue infection following a stone bruise. When he arrived for orthopaedic treatment, the diabetes was again controlled.

A Comparison of Foot Forms Among the Non-Shoe and Shoe-Wearing Chinese Population*

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This investigation was stimulated by statements that foot deformities are hereditary and develop in people who have never worn shoes[2]. However, we believe that foot deformities are of recent origin in the history of man, dating back only to the introduction of footwear. The only deformity of the feet that we can find occurring prior to the wearing of shoes is atrophy of the fifth toe portrayed in Grecian and Roman sculptures. This condition appears to have been caused by the constricting strap of the sandals worn in those times. We felt that an investigation comparing foot forms of the local population should be undertaken; since the population was gradually taking to shoes, such a comparison might not be possible in the future.

TABLE I

DISTRIBUTION BY AGE AND SEX OF SUBJECTS EXAMINED

	Shod		Unshod	
	Male	Female	Male	Female
Youngest subject (*Years*)	4	9	3	1½
Oldest subject (*Years*)	70	53	50	70
Total subjects examined	79	39	17	90

A perusal of the literature showed that there is considerable information about the condition of feet in both the non-shoe-wearing and shoe-wearing peoples; however, no comparison between the unshod and the shod portions of the same population has been reported.

Hoffmann concluded that until the individual starts to wear shoes, the shape of the foot and its range of voluntary and passive motion are practically the same in barefooted and shoe-wearing peoples. The wearing of shoes, usually begun at the end of the first year, compresses and splints the foot; following this, there is progressive narrowing of the anterior portion of the foot and diminution in the range of motion of the phalangeal, tarsal, and ankle joints. Engle and Morton, in a survey of foot disorders among natives of the Belgian Congo, concluded that foot problems were not urgent among the natives from an orthopaedic standpoint. Their foot trouble was chiefly surgical, caused by trauma in some, and by infection in the vast majority. Emslie, reporting on the feet of 281 children between the ages of two and four years old seen at the Woolwich Toddler's Clinic, found that 80 per cent of the children had deflection of the terminal phalanx of the great toe and 30 per cent had incurvation of the fourth and fifth toes. These deformities were not found in children of walking age who had not worn shoes. She concluded that wearing shoes should be avoided during childhood whenever possible to preserve the natural functions of the feet. James described the feet of barefooted natives of the Solomon Islands and stated that he found no deformities of the feet. Wilkins, in his paper, gave figures for the prevalence of foot

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Fig. 1: Dorsal view of unshod feet showing atrophied, jagged toenails and marked skin creases.

Fig. 2: Photograph of unshod feet showing multiple minor lacerations, thick keratinized layer, and prominent skin creases.

disorders among school children in Birmingham, England. In defining the normal foot, he used an unshod foot as a typical example. Brooke thinks that unsatisfactory shoes, and perhaps stockings, are the cause of the great majority of foot troubles. Jelliffe and Humphreys, in a survey of Nigerian troops, described unshod native feet as having deep fissures of the sole, pitting of the plantar surface, fissures of the rim of the heel, erosion of plantar skin, and posterolateral thickening of the heel. They attributed these features to repeated traumata.

Fig. 1

Fig. 2

This paper is a report of a survey made on a portion of the Chinese population to compare foot forms and foot ailments between two groups. The group in which shoes were not worn was chosen from the fishing population who live aboard their boats. To represent the shoe-wearing category, we decided to examine the feet of all patients admitted to the University Surgical Wards of the Queen Mary Hospital during the month of April 1956 (Table I). This group was chosen because: they represented the shoe-wearing population of the Chinese in Hong Kong; their primary complaint for admission was not related to their feet; and they had been using some type of footwear all their lives. It was extremely difficult to examine the men who did not wear shoes since they were out working or fishing most of the time.

UNSHOD FEET

The feet of the non-shoe-wearing population showed thick soles with prominent skin creases apart from many minor lacerations due to traumata. The pachydermatous skin on the sole of the foot had an extraordinarily thick keratinized layer about 0.5 to one centimeter thick which permitted the individual to walk about without any discomfort. Although thick and tough, the skin was pliable and was marked by deep transverse folds which were similar to the lines of joint flexion found on the palm of the hand (Figs. 1 and 2). The skin on the dorsum of the foot presented minute though well marked folds, similar to those seen on the back of the hand. The depth and distinctness of these folds were probably due to the constant movements of the phalangeal and tarsal joints with concomitant intermittent folding of the skin. The toenails were thick, cornified, and short with uneven and jagged edges. This was due to contact with hard stones and other objects on the ground. Most of the subjects examined had well developed

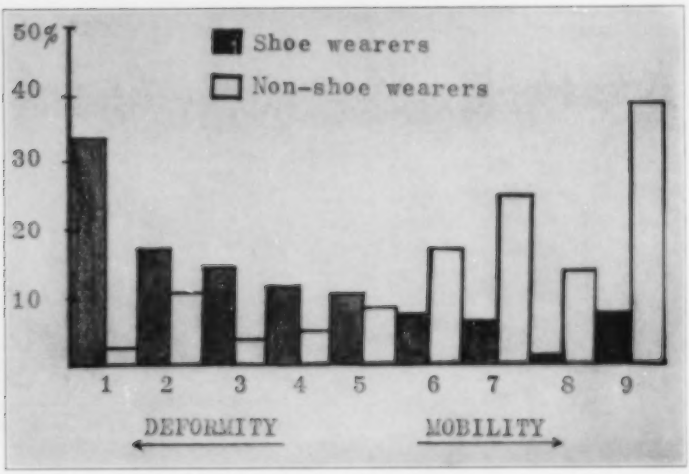

CHART I

This chart shows the frequency of deformity in relation to mobility. The numbered bars represent the following: *1*, hallux valgus; *2*, hallux rigidus; *3*, varus fifth toe; *4*, hammer-toe; *5*, flat-foot; *6*, metatarsus atavicus; *7*, metatarsus primus varus; *8*, hypermobility of the metatarsus; and *9*, metatarsus latus.

arches. Even while walking, the arch was very evident, and those who had a degree of flat-foot did not have any complaints.

Because of the constant immersion of their feet in water, most of the subjects who do not wear shoes showed some degree of swelling; in many, it was not marked. This must cause considerable laxity of tissues and, with that, we expected a variety of foot complaints; however, that was not the case.

The fore part of the foot had a tendency to spread; this was most marked between the big and second toe. The big toe showed a remarkable degree of pre-

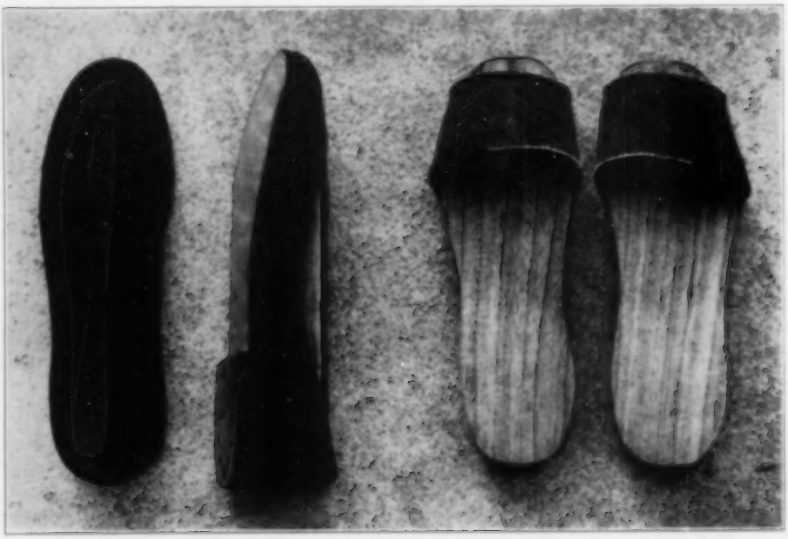

FIG. 3

Photograph showing the two forms of footwear commonly worn by the Chinese. On the right are wooden clogs, or kehk, and on the left are canvas shoes. Note the thin sole and absence of laces for adjustment.

TABLE II

FREQUENCY OF DEFORMITIES AMONG SHOD AND UNSHOD

Deformity	Shod (*Per cent*)	Unshod (*Per cent*)
Hallux valgus	33	1.9
Hallux rigidus	17	10.3
Varus fifth toe	14.4	3.7
Hammer-toe	11	4.7
Flat-foot	10.1	7.5
Metatarsus atavicus	7	16.8
Matatarsus latus	7	38.3
Metatarsus primus varus	6	24.3
Bound feet	1.5	
Hypermobility of the metatarsus	0.9	13.1

hensile strength since it was often used to hold fishing nets and fishing lines taut so that the hands were free. The prehensile strength of the fore part of the foot was also called into play to enable the subject to get a good grip while moving about on his rocking boat. This illustrates foot function when the foot is unrestricted by shoes. Other affections of the fore part of the foot detected were metatarsus primus varus (24.3 per cent) and hypermobility of the metatarsus (13.1 per cent). However, in this group of subjects with a high degree of derangement of the metatarsus, complaints referable to the fore part of the foot were nonexistent. Mobility of the foot was the most striking finding in our whole survey. The unshod foot had laxity of the joints and tissues producing, in its natural form, a flexible foot with a degree of metatarsus latus, metatarsus primus varus, and hypermobility.

SHOD FEET

There are various types of footwear worn by the shoe-wearing Chinese (Fig. 3). The three principal types are:

1. The kehk (wooden clog) is the common type of footwear worn around the house, and consists of a wooden base cut out to conform with the shape of the sole of the foot. At the front part, a piece of stiff leather about one to one and one-half inches wide is attached. To wear it, an individual must squeeze the fore part of his foot in until the strap is tight against the widest portion of his foot, the line drawn from the end of the little toe to the base of the great toe.

2. The canvas shoe is a typical type of footwear and has a thin leather sole. The top is open and the feet are slipped in through this opening. In order to keep the shoe on it must fit tightly since there is no possibility for adjustment. The foot, especially the fore part, is squeezed into a confined area—often the contour of the little toe can be seen bulging through the canvas.

3. The leather shoe is the type of shoe worn by the poorer classes. It is made of low-grade leather with a thick reinforced sole usually cut from an old automobile tire.

The deformities present in those who wore shoes were common and numerous, although none of the subjects complained. There is an interesting comparison (Chart I and Table II) between the deformities in the shod and unshod. We see that mobility and deformity are in inverse proportions; as mobility increases, deformity decreases. This conclusion is best exemplified by the classic deformity found in people whose feet had been bound. This occurs more frequently in the older age group since the custom has long since been condemned.

Callosities on the sole were frequent in the feet of those who wore shoes. On the weight-bearing points—the heel and heads of the first and fifth metatarsals, there was the expected thickening of the sole. Over the lateral aspects of the fifth metatarsal especially, the skin was thick and showed the effects of friction from footwear. In those who had metatarsus atavicus, the abnormally short

first metatarsal caused weight-bearing to be taken over by the head of the second metatarsal. Inevitably in these subjects there was a patch of thickened skin on the sole of the foot over the head of the second metatarsal. This patch is pathognomonic of a short first metatarsal and in many subjects it was used as a diagnosis before complete clinical examination and roentgenograms confirmed the diagnosis of metatarsus atavicus.

CONCLUSIONS

The foot in its natural unrestricted form is mobile and flexible without any of the static complaints often encountered. When the foot becomes restricted by the wearing of stockings and shoes, its natural form becomes altered and static deformities develop.

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de Quervain's Disease

A Clinical and Anatomical Study

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In 1892, Tillaux, in the *Traité d'Anatomie Topographique*, referred to an inflammation localized in the groove of the tendons of the abductor pollicis longus and the extensor pollicis brevis characterized by a small tumor and intense pain when the patient moved his thumb. He felt that this condition resulted from fatigue and improved after a few days' rest. Tillaux referred to it as tenosynovitis *crépitante* or *d'ai*.

In 1895, Fritz de Quervain [6] published five cases of the new entity, which he called *fibröse, stenosierende Tendovaginitis*. In a new publication in May 1912, de Quervain[7] reported another eight cases, all of them cured by surgical treatment, and offered opinions on the etiology and pathogenesis of the syndrome.

In 1930, Finkelstein reviewed the literature and reported twenty-four additional cases. He felt that chronic trauma should be considered the principal cause of the syndrome. From his work, the author derived the well known Finkelstein sign*, which is considered pathognomonic of the disease. In reality, Finkelstein transcribed the test described by Eichoff in 1927.

In 1952, Françon and associates described a case of stenosing tenosynovitis in which a very small osseous spicule was present on the surface of the distal end of the radius. They attributed Finkelstein's sign to Soeur.

GENERAL CONSIDERATIONS

De Quervain drew attention to a common disease and its symptoms, studied the etiology, proposed treatment, and, in repeated publications, gave proof that the syndrome is easy to recognize.

Since the disease is more common among persons who perform manual work such as household servants, weavers, typists, or nurses, it forms a medicosocial problem that has a tendency to worsen because of the requirements of modern industrialization.

Eschle and Winterstein cited rheumatic disposition as a cause of tenosynovitis. Later, it was more aptly described as a special reaction of the mesenchymal tissue to various stimuli. There are cases of tenosynovitis included in the clinical picture of rheumatoid disease so that it is not exaggerated to group de Quervain's disease among the collagen diseases.

The unique mobility of the human thumb contributes to the development of the syndrome. In fact, the tendons of the long extensor muscles of the thumb are subject to fairly acute angulations and to traumata due to friction.

It is interesting to observe that man, after having abandoned the quadruped position, began to make more use of his hands. The thumb was the digit that underwent the greatest evolution, constituting, by itself, one of the branches of the pincers that grasp, secure, and manipulate objects. It has a wide function and can be moved in all planes; it can be delicate and gentle, or firm and violent on pressure. It is for this reason that nature endowed the human thumb with more muscles and tendons. In fact, among mammals, some primates excepted, only the

* To demonstrate the Finkelstein sign, the patient is asked to place the thumb within the hand and hold it tightly with the other fingers. An intense pain will be experienced on the styloid process of the radius, exactly at the tendon sheath, when the hand is bent in ulnar adduction. When the thumb is extended, the pain disappears, even if adduction is maintained.

tendon of the abductor pollicis longus or its equivalent is observed. The extensor pollicis brevis is absent. In the Rhesus monkey, there is normally only one tendon for the abductor longus. Occasionally, the tendon may be divided into two bundles, one for the metacarpal and the other for the sesamoid bone [6]. In the Hylobates, the existence of a more or less separate extensor pollicis brevis and a tendency to fasciculation of the abductor pollicis longus can be seen. In the Homo sapiens, specialization achieved an extraordinary anatomicofunctional richness: the abductor pollicis longus with three to four individual tendons and with multiple insertions and the extensor pollicis brevis with one or more tendons. Nevertheless, one may observe regressive tendencies such as the absence of the extensor pollicis brevis or even of the abductor pollicis longus.

STUDIES ON CADAVERA

The frequent finding, during surgery, of one or more aberrant tendons, as they were called by Bunnell, prompted us to dissect fifty wrists of twenty-seven

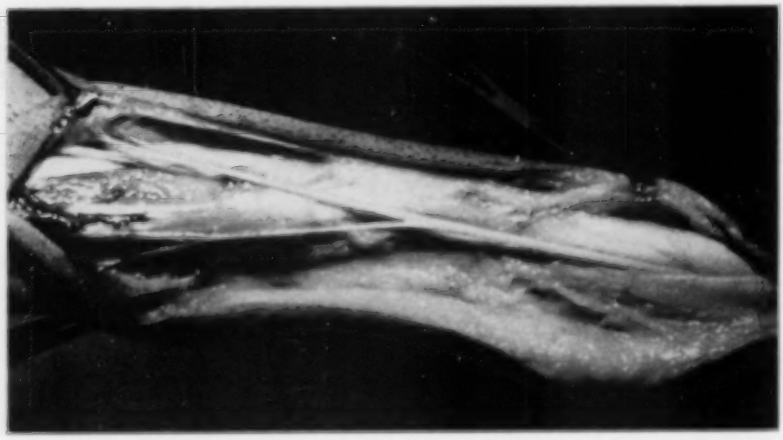

FIG. 1

Dissection showing the superficial radial nerve bifurcated one inch above the first radial canal of the wrist.

fresh cadavera. Twenty were male, and seven were female. There were eight fetal wrists and forty-two adult wrists. A longitudinal incision was made along the lower third of the forearm, the radial region of the wrist, and the radial border of the hand and thumb. Photographs were made of all the dissections, and no artifice was used to enrich the details of the anatomical structures. Although the dissections were fairly extensive, the photographs obtained were limited to the osteofibrous canal. Our attention was mainly limited to the structures which formed the anatomical basis of de Quervain's disease.

The results of the dissections of the cadavera are the following:

1. The superficial radial nerve traversed the radial region of the wrist eighteen times (36 per cent) without subdividing; twenty-five times (50 per cent) bifurcated (Fig. 1), and seven times (14 per cent) trifurcated.

2. Thirty-eight wrists (76 per cent) presented one single osteofibrous groove, and twelve wrists (24 per cent) had a double groove (Fig. 2).

3. In thirty-seven wrists (74 per cent), there was one common synovial sheath for all the tendons; in thirteen wrists (26 per cent), there was one sheath for each tendon.

4. In twenty-nine wrists (58 per cent), three tendons were found (Fig. 3); in twelve wrists (24 per cent), two tendons (Fig. 4); in seven wrists (14 per cent),

four tendons (Fig. 5); in one wrist (2 per cent), five tendons (Fig. 6); and in one wrist (2 per cent), only one tendon.

5. In twenty-nine wrists (58 per cent), we observed the existence of one accessory tendon; in seven wrists (14 per cent), two tendons; and in one wrist (2 per cent), three tendons.

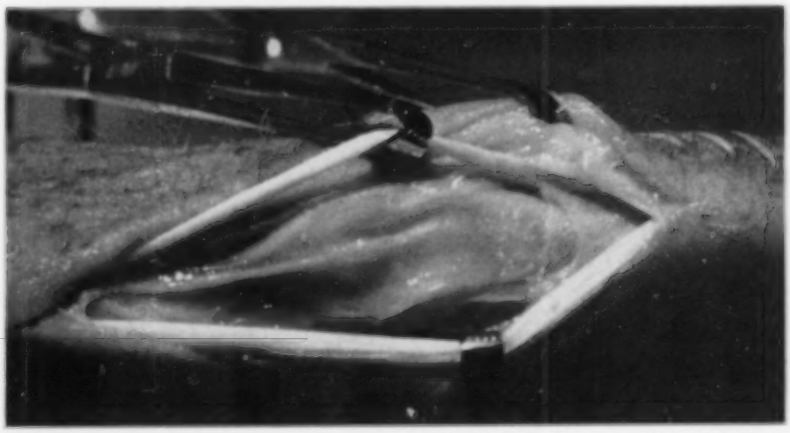

FIG. 2

A double groove is seen, one for the extensor pollicis brevis tendon and the other for the abductor pollicis longus tendon. It is very important, during surgery, to remember the possibility of a double canal.

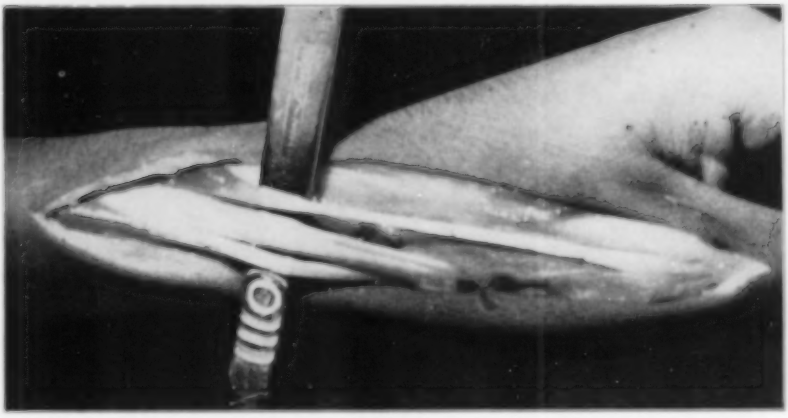

FIG. 3

Three tendons are seen, one for the extensor pollicis brevis and two for the abductor pollicis longus, the principal tendon and its accessory.

6. In twenty-nine wrists (58 per cent), the abductor pollicis longus presented two tendons at the level of the osteofibrous groove; in thirteen wrists (26 per cent), one tendon; in seven wrists (14 per cent), three tendons; and in one wrist (2 per cent), four tendons.

7. In forty-five wrists (90 per cent), the extensor pollicis brevis had one tendon, and in two wrists (4 per cent), two tendons. The tendon was absent in three wrists (6 per cent).

8. The abductor pollicis longus was inserted in thirty-nine wrists into the distal portion of the first metacarpal; in twenty-one wrists, into the greater mult-

angular; in twenty wrists, into the abductor pollicis brevis; in twelve wrists, into the opponens pollicis; in six wrists, into the thenar fascia; in three wrists, into the flexor pollicis brevis; and in one wrist each into the carpometacarpal joint and the proximal phalanx of the thumb.

9. The extensor pollicis brevis was inserted in thirty-eight specimens into the distal portion of the proximal phalanx of the thumb and in nine specimens into the distal phalanx.

There were sixty-four tendinous variations of the abductor pollicis longus in the fifty wrists studied.

From the study, we found that the use of the term *aberrant* or *anomalous* for the accessory tendons found in the first radial groove of the wrist is not exact. The fasciculation observed is the result of the specialized function of the thumb.

ETIOLOGY

In this series, 28 per cent of the patients reported trauma which had occurred three to twelve months prior to examination. Direct trauma was reported twice

FIG. 4

Two tendons, a well developed abductor pollicis longus and a very thin extensor pollicis brevis, are seen.

(6 per cent), and indirect trauma, seven times (22 per cent). In six (19 per cent) of twenty-three cases (72 per cent) there was no well defined trauma, the history disclosing some functional excess.

It is evident that trauma cannot be considered the sole cause of tenosynovitis stenosans. The work of the tendons of the long abductor and short extensor of the thumb in the first osteofibrous canal of the wrist is done under reasonable conditions. The finding that the tendon does not stand more than 2,000 excitations per hour [5] does not imply that tenosynovitis of the wrist is due to one single cause such as functional excess. When one remembers the tremendous work to which the digital tendons of the concert pianist are subjected one cannot deny the role which trauma, especially repeated trauma, plays. However, trauma does not act alone; it is often associated with a predisposing constitutional factor or connected, at times, with the collagen diseases.

Some of our observations strongly suggest that this predisposing factor plays a very important role. In two patients, we could clearly verify that de Quervain's syndrome foreshadowed the development of rheumatoid arthritis. One of these wrists was even operated on without any benefit (Case 22). Administration of cortisone produced spectacular results in controlling the pain and soon enabled the patient to resume her activities as a nurse (Fig. 7).

OBSERVATIONS

In our study of thirty-two wrists in twenty-nine patients, twenty-seven (84 per cent) of the patients were female, and five (16 per cent) were male. Twenty-six (81 per cent) were white, six (19 per cent) were colored.

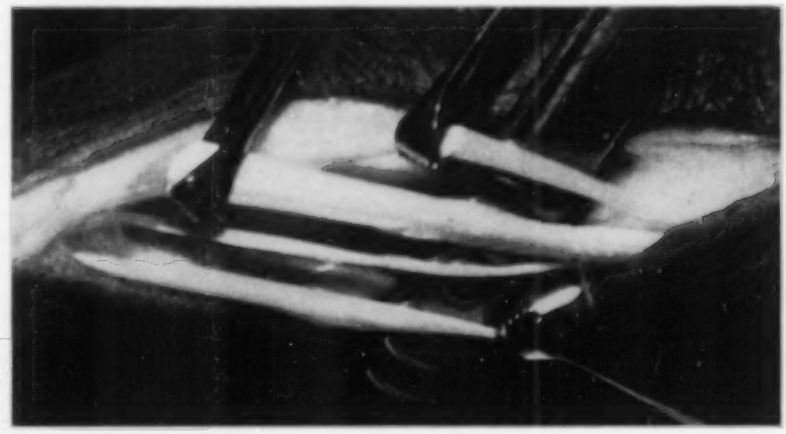

FIG. 5

Four tendons, a very fragile extensor pollicis brevis and a fasciculate (in three bundles) abductor pollicis longus can be seen.

FIG. 6

Five tendons are seen, an extreme fasciculation of the abductor pollicis longus tendon and one bundle for the extensor pollicis brevis.

Sixteen of the patients were engaged in domestic work; five were employed as bookkeeper-typists; four were nurses; and two were weavers and embroiderers. Of the remaining five, there was a policeman, a butler, a workman, a lamplighter, and a retired public official. The right side was involved eighteen times (56 per cent) and the left side fourteen times (44 per cent).

Patients between the ages of twenty and twenty-nine years were the most affected (ten wrists). Seven wrists were involved in patients between thirty and thirty-nine years; five in those between forty and forty-nine; six in those between fifty and fifty-nine; two in those between sixty and sixty-nine; and two in those between seventy and seventy-nine years.

TABLE I

DATA ON TWENTY-NINE PATIENTS WITH DE QUERVAIN'S DISEASE

Case	Sex and Race	Age	Occupation	Trauma	Side	Treatment	Immediate Result (*Finkelstein's Sign*)	Final Result
1	F, W	30	Domestic	No	R	Conservative	Positive	Lost
2	F, W	44	Bookkeeper-typist	Yes	L	Refused	No test	Cured
3	F, W	30	Domestic	Yes	R	Conservative	Negative	Cured
4	F, W	37	Domestic	Yes	L	Surgery	Negative	Cured
5	F, W	24	Weaver	Yes	L	Conservative	Positive	Cured
6	F, W	27	Domestic	No	L	Conservative	No test	Cured
7	M,W	42	Policeman	Yes	R	Conservative	Strongly positive	Cured
8	F, W	51	Bookkeeper-typist	No	R	Conservative	No test	Cured
9	F, W	24	Domestic	No	R	Conservative	Negative	Lost
10	F, W	25	Domestic	No	R	Conservative	Strongly positive	Cured
11	F, C	66	Domestic	No	R	Surgery	Positive	Cured
12	F, C	35	Nurse	No	R	Conservative	Strongly positive	Cured
13	F, W	71	Domestic	No	L	Conservative	Positive	Cured
14	M,W	27	Lamp-lighter	Yes	R	Surgery	Negative	Cured
15	F, W	54	Domestic	No	L	Surgery	Negative	Cured
16	F, C	26	Domestic	No	R	Surgery	Negative	Cured
17	F, W	50	Typist	Yes	R	Conservative	Positive	Cured
18	F, C	38	Domestic	No	L	Refused	No test	Cured
19	F, W	29	Nurse	No	R-L	Conservative	Negative	Cured
20	F, W	54	Domestic	No	R-L	Conservative	Strongly positive	Cured
21	M,W	27	Butler	Yes	L	Surgery	Negative	Cured
22	F, W	42	Nurse	No	R	Surgery	Strongly positive	Cured
23	M,W	71	Retired public offical	No	R	Conservative	No test	Lost
24	F, W	45	Domestic	No	R	Conservative	Strongly positive	Cured
25	F, W	48	Domestic	No	L	Surgery	Negative	Cured
26	F, W	35	Typist	No	R-L	Conservative	Positive	Cured
27	F, C	20	Weaver	No	L	Conservative	Strongly positive	Lost
28	M,C	50	Workman	Yes	L	Surgery	Negative	Cured
29	F, W	60	Domestic	No	R	Conservative	Positive	Cured

The symptoms appeared suddenly in eight wrists, and gradually in twenty-four wrists. Pain was the predominant symptom, and was noted in every patient. Localized pain on the radial border of the wrist was noticed in thirty-one wrists; referred pain in nine wrists; pain radiating to the thumb in twelve; pain radiating to the forearm in ten; and to the forearm and arm in two.

A visible or palpable tumor on the radial surface of the wrist was found in twenty-six. In twenty-three wrists, Finkelstein's sign was strongly positive and in nine, it was positive. Eight patients complained of spontaneous pain, especially severe at night, sometimes interfering with sleep.

A roentgenographic study was carried out on twenty-two wrists. Of these, six appeared normal, eleven had localized osteoporosis, six showed periosteal reaction, two had hypertrophic arthritis, and one had diffuse osteoporosis, and one had atrophic arthritis. In only one patient was the Kahn test positive. Eight patients had a high sedimentation rate (Westergren), between ten and forty-two millimeters in the first hour. Of the thirty-two patients studied with de Quervain's syndrome, seventeen complained of other diseases. Four patients had deltoid bursitis, five had generalized articular pains, two had torticollis, and five patients had miscellaneous conditions such as diabetes or heart disease.

FIG. 7

This patient, a nurse, was operated on without results; the pain was controlled by cortisone.

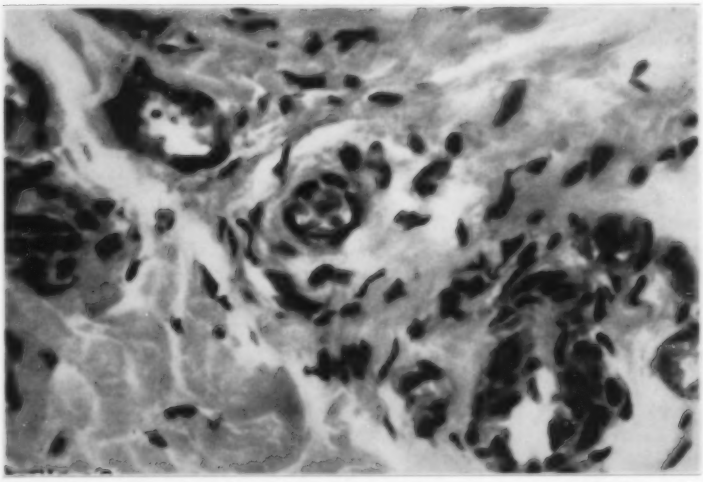

FIG. 8

This photomicrograph shows fibrosis and slight lymphocytic infiltration. Note the proliferation of endothelial cells of small blood vessels (hemotoxylin and eosin, × 120).

Nine wrists were operated on, and twenty-one were treated conservatively. Two patients refused treatment. Histological sections (Fig. 8) were obtained from eight wrists. Surgical treatment consisted in removing the fibrous covering of the canal located at the distal end of the radius. There were three tendons in the osteofibrous groove in three wrists; once four tendons were found. In five wrists there were only two tendons—one for the abductor pollicis longus and the other for the extensor pollicis brevis.

The conservative treatment consisted in plaster immobilization of the wrist, with the thumb in slight abduction, for a period of from two to six weeks. This

was not always sufficient to control the pain; therefore, an analgesic drug, such as aspirin or phenylbutazone, was simultaneously employed.

Beginning in 1953, the use of hydrocortisone in dosages of twelve milligrams injected locally was begun. At first, the drug was indiscriminately administered; later, after some experience was gained, hydrocortisone was used only in those patients who had a short history of discomfort and in whom the condition was limited to synovitis or to a mild fibrous thickening of the structures surrounding the tendons. It was found that the results were delayed and unpredictable in patients who had had a chronic condition or a conspicuous tumor. In recent patients, local injections of hydrocortisone, analgesic drugs, and plaster immobilization of wrist and thumb afforded results leading to complete relief in an average period of three weeks.

Of the twenty-one wrists conservatively managed, ten were treated by plaster immobilization and analgesic drugs; six, by local injection of hydrocortisone; and five, by local injection of hydrocortisone, plaster immobilization, and aspirin.

For the late results of our series, twenty-five patients (78 per cent), all of whom were treated more than two years previously, were re-examined. A complete cure was observed in all of these patients. It is interesting to note that even the two patients who refused treatment were also free from symptoms.

It is evident that surgical treatment offers quicker and more definite cures than conservative treatment. However, the cure does not depend on the type of treatment instituted. Patients with a strongly positive Finkelstein's sign (Cases 7, 10, 12, and 20) were all asymptomatic on re-examination. One patient with a positive (Case 11) Finkelstein's sign who had been treated surgically was asymptomatic on re-examination.

De Quervain's syndrome runs an apparently cyclical course and tends to be cured completely within a variable length of time, depending upon the general condition of the patient.

CONCLUSIONS

1. De Quervain's syndrome may be considered an occupational disease in many cases.

2. Its cure is very frequently accompanied by a predisposition to rheumatoid arthritis. De Quervain's disease may be an integral part of the clinical picture of rheumatoid arthritis or the collagen diseases.

3. The anatomical findings suggest that the existence of more than two tendons in the radial osteofibrous groove should not be considered abnormal.

4. The phylogenic development of the thumb also forms a plausible motive for the modification of the classic concept of de Quervain's disease.

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Tendon Transfers to Restore Function of Hands in Tetraplegia, Especially after Fracture-Dislocation of the Sixth Cervical Vertebra on the Seventh*

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The number of patients who sustain and survive severe neurological deficits after injuries of the cervical portion of the spinal cord is increasing. The disability of many of these patients originates from fracture-dislocation of the sixth cervical vertebra on the seventh, or that of the seventh cervical vertebra on the first thoracic vertebra.

When the injury is at the level between the seventh cervical and the first thoracic vertebra, an appreciable number of functioning muscles are available for transfer of their tendons to ameliorate the difficulty. Transfer of the flexor carpi radialis to the flexor digitorum profundus, the brachioradialis to the flexor of the thumb, and the flexor carpi ulnaris to oppose the thumb, as advocated by Bunnell [1, 2], is usually the procedure of choice in lesions at this level of the spinal cord. If it is evident that clawing will be a problem, this surgical procedure should be preceded as a separate operation by a Fowler transfer whereby the tendons of the extensor indicis proprius and the extensor digiti quinti proprius are divided longitudinally, are passed through the spaces of the interossei and through the canals of the lumbricales anterior to the transverse metacarpal ligament, and then are inserted into the combined intrinsic extensor aponeurosis of each finger. If clawing is not a problem, the extensor indicis proprius should be transferred at the time of the flexor and opponens transfers, as advocated by Bunnell [1, 2], to abduct the index finger.

When the injury is higher than the sixth cervical vertebra and is accompanied by severe trauma to the spinal cord, the patient often does not survive for long. If he does survive, tenodesis is all that usually can be offered.

When the injury is at the level between the sixth and the seventh cervical vertebra, all motor muscles of the fingers, including the intrinsic muscles, are paralyzed. Most of the patients so affected have only the following muscles functioning below the level of the elbow: extensor carpi radialis longus, extensor carpi radialis brevis, brachioradialis, flexor carpi radialis, and pronator teres (Fig. 1). In our experience, this pattern of available functioning muscles below the elbow is the commonest type in patients who have tetraplegia resulting from injury of the cervical portion of the spinal cord. In 1955, Riordan[3] suggested the basic tendon transfers outlined here for such patients. We have made certain modifications of Riordan's plan whereby his tenodesis procedure is added and a slip of the extensor carpi radialis brevis is transferred to the abductor pollicis longus.

At times, because of the nature of the injury, the power of the flexor carpi radialis and pronator teres is greater on one side than on the other. If both these muscles are too weak for transfer, tenodesis to furnish flexion of the fingers and

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opposition of the thumb can be utilized. Slight weakness is not a contra-indication to the following surgical procedures, which will restore appreciable function for grasping and light pinching.

SURGICAL TECHNIQUE

Surgical correction is done in two steps.

Operation 1 (Fig. 2)

The extensor carpi radialis brevis is undisturbed to allow dorsiflexion of the wrist. On occasion, a slip of the tendon of this muscle is transferred to the tendon of the abductor pollicis longus. The Riordan tenodesis [4] is done, when indicated, to

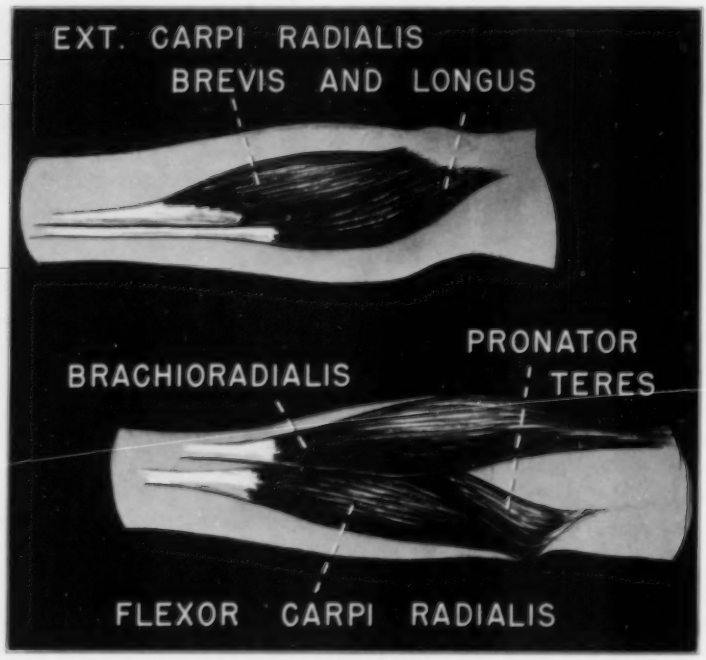

FIG. 1

Drawing showing the five muscles usually functioning below the elbow after severe injury of the spinal cord between the sixth and the seventh cervical vertebra. The upper part is a dorsal view and the lower part is a volar view.

prevent hyperextension of the metacarpophalangeal joints and subsequent clawing of the fingers. The tendon of the extensor carpi radialis longus is transferred to the long extensor tendons of the fingers and thumb. The tendon of the extensor pollicis longus may be relocated so that it pulls more straightly over the base of the first metacarpal.

Operation 2 (Fig. 3)

The flexor carpi radialis, lengthened by means of the tendon of the palmaris longus or one of the sublimis muscles, is transferred, and a fixed pulley made from the tendon of the flexor carpi ulnaris is used to restore opposition of the thumb. The pronator teres, lengthened by means of a strip of attached periosteum or a tendon of the flexor digitorum sublimis, is transferred to the flexor digitorum profundus tendons of the fingers. The tendon of the brachioradialis is transferred to the flexor pollicis longus (the excursion of the brachioradialis is so short that this muscle functions poorly when used otherwise).

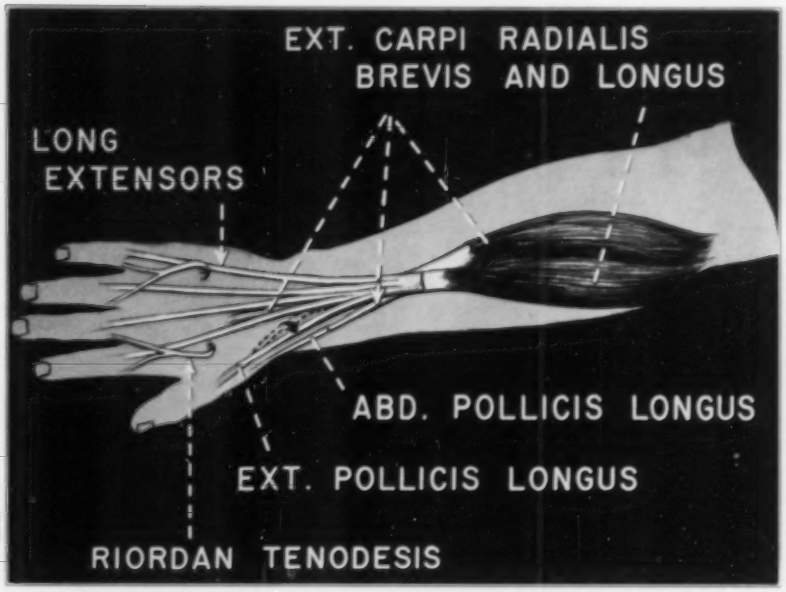

FIG. 2

Tendon transfers that may be performed during the first operation in patients with tetraplegia due to injury of the spinal cord between the sixth and the seventh cervical vertebra.

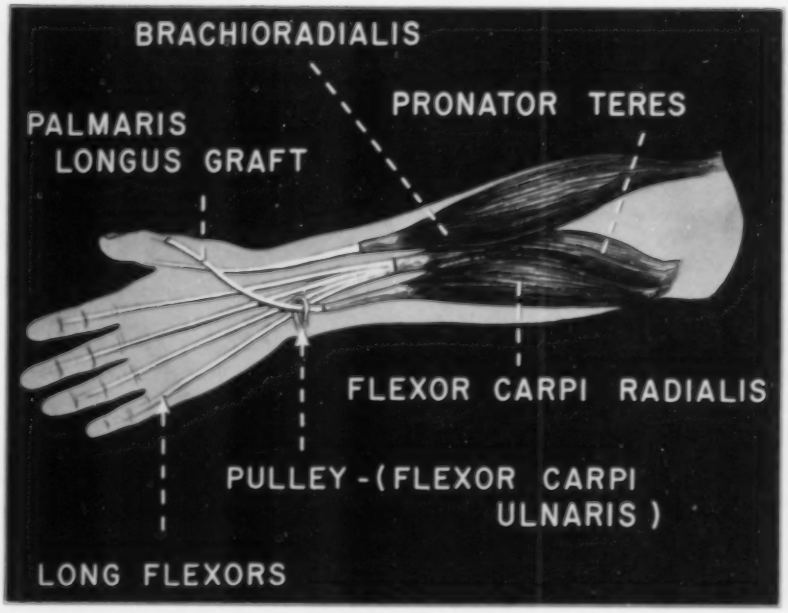

FIG. 3

Tendon transfers that may be performed during the second operation in patients with tetraplegia due to injury of the spinal cord between the sixth and the seventh cervical vertebra.

The transfer of these tendons utilizes the function of automatic motion of the fingers that occurs with movement of the wrist (Fig. 4). Arthrodesis of the wrist rarely, if ever, should be done in patients who have tetraplegia.

Anaesthesia

It has been our experience that these patients tolerate modern general anaesthesia without undue risk. Because of the sensory impairment, only light general anaesthesia is required. Respiration and adequate oxygenation are easily maintained by a competent anaesthesiologist with the aid of an anaesthetic machine. The patient usually awakens almost immediately when the anaesthesia is terminated. We consider that the use of brachial-block anaesthesia and its accompanying slight risk of pneumothorax creates a greater hazard to these patients, who have

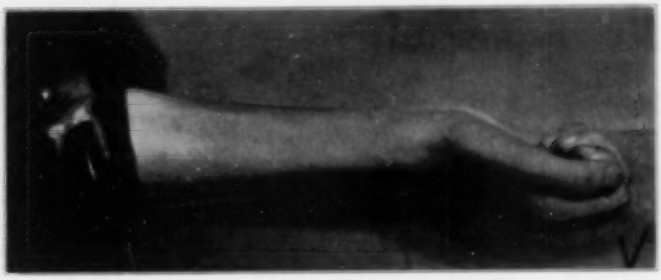

FIG. 4

Photograph of the right hand of a patient with tetraplegia prior to tendon transfers. With the wrist extended, the fingers and thumb assume a position of semiflexion but active motion is not possible.

greatly decreased vital capacities, than does general anaesthesia correctly administered. No particular difficulties from the use of general anaesthesia were encountered in our patients.

Splinting and Muscle Re-education

If a Riordan tenodesis is done at the time of the first surgical procedure (Operation 1), the wrist should be splinted in full extension, the proximal finger joints in slight flexion, and the middle and distal joints in extension. If a Riordan tenodesis is not done, the metacarpophalangeal joints are extended. The dressings are not disturbed for four weeks.

The patients are then taught, under the direction of a competent physiatrist, to extend the fingers, using the transferred extensor carpi radialis longus. It is important that passive stretching be avoided. Between the two surgical procedures, the patients are encouraged to be as active as possible. Usually two months after the first operation, the joints have been mobilized to such a degree that one can proceed with the second surgical procedure. After this, the wrist is splinted in flexion and the fingers in the position of function for four weeks. Then the patient is taught to flex and extend the fingers and to oppose the thumb (Figs. 5-A, 5-B, 5-C, and 6).

Although tendons of antagonistic muscles are used in part of the transfer, the patients experienced little difficulty in learning to use these transfers.

RESULTS AND COMMENT

During the past three years, we have transferred tendons in seven tetraplegic patients who had lesions of the cervical portion of the spinal cord between the sixth and the seventh cervical vertebra, two patients in whom the injury was one segment higher, one patient in whom the injury was one segment lower, and one

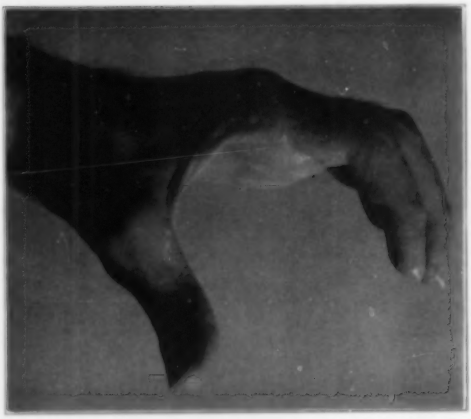

FIG. 5-A

FIG. 5-B

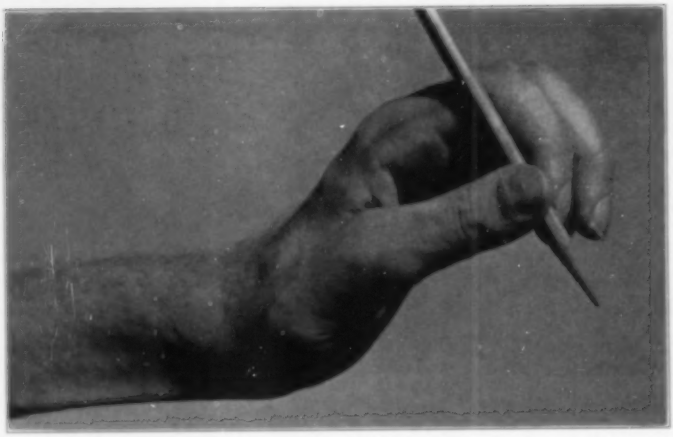

FIG. 5-C

Figs. 5-A, 5-B, and 5-C: Postoperative photographs showing range of motion after two-stage tendon transfers in a patient with tetraplegia resulting from fracture-dislocation of the sixth cervical vertebra on the seventh. Fig. 5-A: Extension. Fig. 5-B: Grasping. Fig. 5-C: Pinching.

patient who had spastic hemiplegia associated with compression fracture of the fifth cervical vertebra (Table I).

The seven patients in the first category were unable to move the fingers actively to the slightest degree; however, they had sufficient strength in the extensor carpi radialis longus, the extensor carpi radialis brevis, the brachioradialis, the flexor carpi radialis, and the pronator teres of at least one upper extremity to warrant the tendon transfers described. In four of these patients (Cases 2, 3, 4, and 5), strength was such that bilateral transfers could be performed. Arthrodesis of the left wrist was performed in Case 1 in an attempt to gain stability and strength. Despite the many surgical procedures done on this patient (ten in all), we were never able to overcome effectively the clawing that developed on the left, and the strength of grasp and pinch did not approach that gained on the right. The muscular strength prior to arthrodesis of the wrist was almost identical on each side. This patient recently died of pneumonia.

Our first patient, as already indicated, had a total of ten surgical procedures, mostly in the left hand. The next patient had eight procedures, six on the right

TABLE I

DATA IN ELEVEN TETRAPLEGIC PATIENTS HAVING

Case	Age (*years*) and Sex	Cause of Injury	Level of Injury	Side	Muscle Strength Prior to Tendon Transfers *											
					Digits, Extensors	Digits, Flexors	Intrinsics	ECU	ECRL	ECRB	APL	FCR	FCU	PT	BR	Wrist Extension
1	19 F	Automobile accident	C6, C7	Rt.	−4	−4	−4	−4	0	0	−4	−1	−4	−1	0	ECRB
				Lt.‡	−4	−4	−4	−4	−1	−1	−4	−2	−4	−1	0	
2	20 M	Diving	C6,	Rt.	−4	−4	−4	−4	0	0	−4	−3	−4	−1	0	ECRB
			C7	Lt.	−4	−4	−4	−4	0	0	−4	−1	−4	0	0	ECRB
3	20 M	Automobile accident	C6,	Rt.	−4	−4	−4	−4	0	0	−4	−2	−4	−2	0	ECRB
			C7	Lt.	−4	−4	−4	−4	0	0	−4	−3	−4	−1	0	ECRB
4	22 M	Diving	C6, C7	Rt.	−4	−4	−4	−4	0	0	−4	−2	−4	−1	0	ECRB
				Lt.	−4	−4	−4	−4	0	0	−4	−2	−4	−1	0	ECRB
5	21 M	Diving	C6,	Rt.	−4	−4	−4	−4	0	0	−4	−1	−4	−1	0	ECRB
			C7	Lt.	−4	−4	−4	−4	0	0	−4	−1	−4	−1	0	ECRB
6	32 M	Diving	C6,	Rt.	−4	−4	−4	−4	−1	−1	−4	−3	−4	−3	0	ECRB
			C7	Lt.	−4	−4	−4	−4	−1	−1	−4	−2	−4	0	0	ECRB
7	45 M	Automobile accident	C6,	Rt.	−4	−4	−4	−4	−1	−1	−4	−2	−4	−1	0	ECRB
			C7	Lt.	−4	−4	−4	−4	−1	−1	−4	−1	−4	0	0	ECRB
8	30 M	Fall from ladder	C5	Rt.	−1	−2	−1	−4	0	0	−1	0	0	0	0	
				Lt.	−4	−4	−4	−4	0	0	−4	−3	−4	−1	0	ECRB
9	37 M	Automobile accident	C5, C6	Rt.	−4	−4	−4	−4	0	0	−4	−2	−4	−2	0	ECRB
				Lt.	−4	−4	−4	−4	0	0	−4	−3	−4	−3	0	ECRB
10	20 M	Automobile accident	C5,	Rt.	−4	−4	−4	−4	0	−1	−4	−4	−4	−3	−2	
			C6	Lt.	−4	−4	−4	−4	0	−1	−4	−4	−4	−3	−2	
11	33 F	Automobile accident	C7, T1	Rt.	0	−4	−4	−2	0	0	−4	0	−1	0	0	
				Lt.	0	−4	−4	−2	0	0	−4	0	−1	0	0	

* ECU = extensor carpi ulnaris; ECRL = extensor carpi radialis longus; ECRB = extensor carpi
PT = pronator teres; BR = brachioradialis; EPL = extensor pollicis longus; EIP = extensor indicis
tween 0 and −4.

† Results expressed in percentage of normal

‡ Wrist fused on left

TABLE I

TENDON TRANSFERS TO RESTORE HAND FUNCTION

Tendons Transferred for *								Results †				Total No. of Operations	Comments
Finger Extension	Thumb Extension	Thumb Opposition	Stability, Metacarpophalangeal Joints	Stability, Base of Thumb	Finger Flexion	Thumb Flexion	EPL Relocated	Pinch	Hook	Grasp	Coordination		
ECRL	ECRL	FCR	Riordan	Tenodesis	PT	BR		25	25	25	15	10	Died of pneumonia, September 1957
ECRL	ECRB	FCR	Riordan		PT	BR		0	25	0	10		
ECRL	ECRL	Tenodesis		Arthrodesis, base	PT	BR		25	25	30	30	8	
ECRL	ECRL	FCR			PT	BR		35	35	40	40		
ECRL	ECRL	Tenodesis; FCR distal	Riordan		Tenodesis; PT distal	BR		10	40	15	20	4	Driving automobile with hand controls
ECRL	ECRL	FCR	Riordan		PT	BR		40	40	50	30		
ECRL	ECRL	FCR	Riordan		PT	BR		40	40	50	30	4	Ambulatory with crutches
ECRL	ECRL	FCR			PT	BR		50	40	50	40		
ECRL	ECRL	Tenodesis	Riordan	Tenodesis	PT	BR		30	30	35	30	7	
ECRL	ECRL	FCR	Riordan	Slip of ECRB	PT	BR	×	20	20	20	25		
		Tenodesis			Tenodesis	BR		10	15	25	15	5	
ECRL	ECRL	FCR		Slip of ECRB	PT	BR		30	30	35	30		
ECRL	ECRL	FCR		Slip of ECRB	PT	BR	×	10	20	25	25	4	Joint stiffness a problem; thumbs adducted
ECRL	ECRL	FCR		Slip of ECRB	PT	BR	×	15	25	30	30		
					Tenodesis; PT distal							5	
Tenodesis	Tenodesis	ECRL				PT		0	50	30	10		
ECRL		FCR		FC[illegible]	PT	PT		30	30	30	25	3	Had severe frostbite of left hand at time of injury
ECRL		Tenodesis		Arthrodesis, base	Tenodesis	BR		10	30	30	25		
		Tenodesis			Tenodesis; BR distal	BR and tenodesis		10	40	20	20	2	
		BR			ECRL			10	50	25	25		
		FCU	Fowler	Slip of FCR	ECRL	BR		55	60	55	45	4	
		FCU	EIP into first dorsal interosseus	Slip of FCR	ECRB	PT		55	60	55	45		

adialis brevis; APL = abductor pollicis longus; FCR = flexor carpi radialis; FCU = flexor carpi ulnaris; roprius; 0 = normal muscle strength; −4 = complete paralysis; −1, −2, and −3 = gradations be-

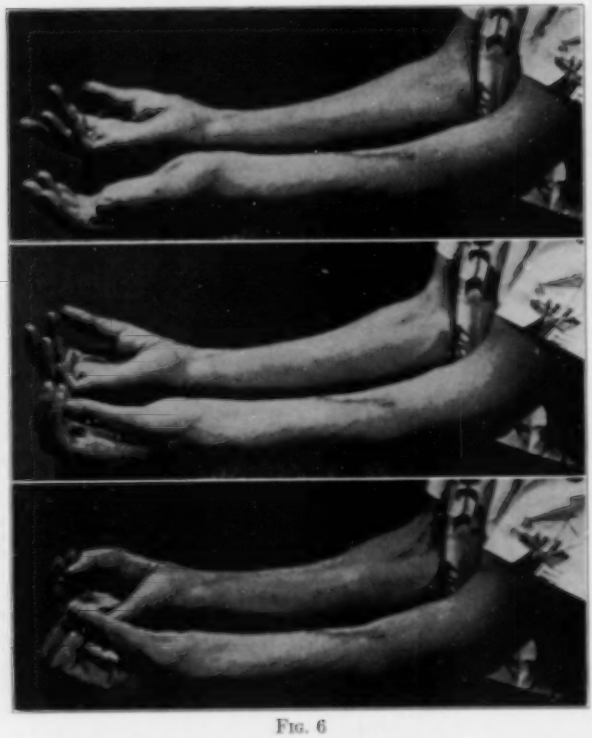

FIG. 6

Postoperative photographs after tendon transfers showing: *top*, active extension of fingers; *center*, attempted opposition of thumbs to index fingers; and *bottom*, grasping performed with fingers and opposing thumbs in a patient with tetraplegia resulting from fracture-dislocation of the sixth cervical vertebra on the seventh.

but only two on the left. In both of these cases, we were developing our techniques and were proceeding slowly. Several operations were of a minor nature and were done to reinsert one or two finger or thumb extensors or flexors that had pulled out after the original transfers. Five procedures, three of them minor, were performed on the right hand in Case 5 because of adherence of tendons or incorrect pull after the original transfers. An extra procedure was also required in Case 6 in an attempt to overcome a lag in extension of the long and ring fingers on the right. Almost without exception, if the patient obtained satisfactory results on one side but poorer results on the other side, he asked us to keep trying until we considered that maximum improvement had been obtained. Four procedures, two on each hand, were necessary for the remaining three patients in this first group of seven. With careful attention to detail and improved technique we now believe that adequate improvement in most patients in this category can be obtained with this minimum number of operations. The last of these seven patients (Case 7) operated on was also the oldest (forty-five years of age). He had considerable joint stiffness and an adduction contracture of his thumbs prior to operation; this situation militated against the best possible result, but he is slowly continuing to make gradual improvement. The most pronounced improvement occurred in Cases 2, 3, and 4. One of these patients is driving an automobile equipped with hand controls; another patient has so strong a grasp that he is able to walk with crutches and braces.

The remaining four patients (Cases 8, 9, 10, and 11) are in different categories, since their injuries were at different levels of the spinal cord. As was ex-

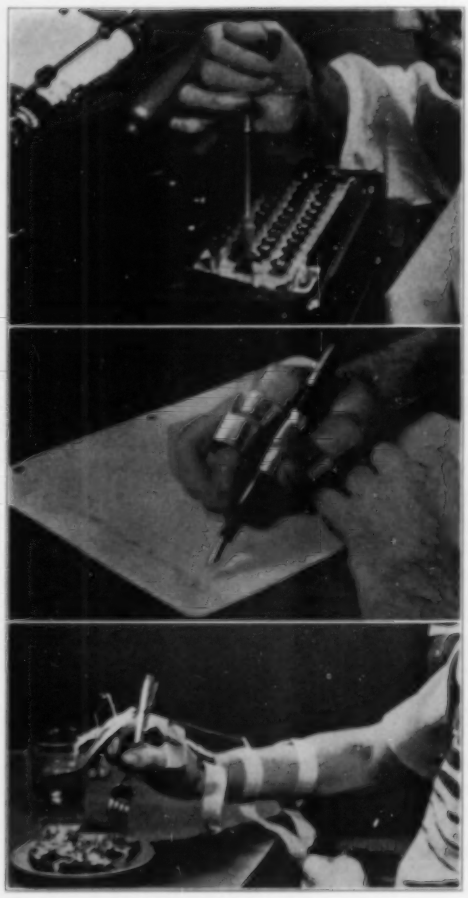

FIG. 7

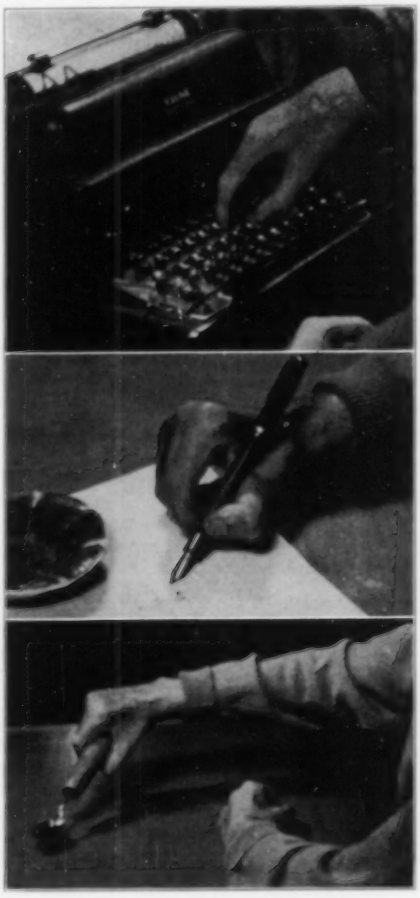

FIG. 8

Fig. 7: Appliances used by patients with tetraplegia prior to tendon transfers: *top*, device used for typing; *center*, device used to clamp pen or pencil; and *bottom*, appliance with movable parts controlled by springs and elastic bands to enable a tetraplegic patient to use various utensils. The assistance of an attendant for application is required.

Fig. 8: Photographs showing ability of a tetraplegic patient after tendon transfers to type, write, and use eating utensils without the aid of appliances.

pected in the last patient (Case 11), an excellent result was obtained from the transfers, since extension of the fingers was possible prior to operation, which was not present in the other patients except one (Case 8), in whom the right hand was essentially normal.

Prior to transfer of the tendons, these tetraplegic patients required various appliances for limited hand function (Fig. 7). These contrivances usually consisted of a rigid part strapped to the forearm; an attachment controlled by springs was fastened to the thumb and fingers in such a way that the patient could hold knives, forks, spoons, pencils, and toothbrushes. Other appliances were rigid; these had slots in which the various utensils could be inserted or locked. Use of most of these instruments required the assistance of an attendant for application and change of each utensil. After transfer of tendons, the patients required no special appliances and were more independent (Fig. 8). The function of all hands having the transfers described was appreciably better than that of hands in which tenodesis only was done and of one with the available muscles

enumerated on which arthrodesis of the left wrist was performed prior to transplantation of tendons.

SUMMARY

The number of surviving patients with tetraplegia following trauma is increasing. Many of these patients are injured between the sixth and the seventh cervical vertebra. These patients have on one side, and often on both, the following muscles functioning below the level of the elbow: extensor carpi radialis longus, extensor carpi radialis brevis, brachioradialis, flexor carpi radialis, and pronator teres.

By two-stage surgical transfer of tendons in each upper extremity, active extension and flexion of all digits, the correction of clawing, and opposition of the thumb can be accomplished. These tendon transfers utilize the function of automatic motion of the fingers that accompanies movement of the wrist. Arthrodesis of the wrist rarely, if ever, should be done in patients who have tetraplegia.

Patients in whom such tendon transfers are done regain the function of hooking, light pinching, and grasping. They are able to discard special hand appliances and become more independent.

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DISCUSSION

Dr. James N. Wilson, Los Angeles, California: In some cases of injury to the spinal cord at the level of the sixth and seventh cervical vertebrae the only functioning muscles available for transfer in the forearm are the radial wrist extensors, pronator teres, and the brachioradialis. When both radial wrist extensors are strong it is safe to use the extensor carpi radialis longus to provide another function. This muscle is suitably used to provide flexion of the fingers because of the synergistic action between the long digital flexors and the wrist extensors, and its greater power and amplitude. Extension of the fingers and thumb is a relatively unimportant function and can be achieved in the mobile wrist by tenodesis of the long extensors and Riordan's tenodesis of the intrinsic muscles to prevent clawing. When the basic functions of grasp and release have been achieved, then it is advisable to utilize the active muscles for supplementary functions such as opposition and flexion of the thumb, individualized voluntary flexion of the index and long fingers, and abduction of the index finger.

In some patients with spinal-cord deficits at a high level, the hand is completely without sensation. If some feeling can be restored the functional result will be improved. Nerve transfer was recently performed in a quadriplegic patient whose only sensation below the elbow was supplied by the musculocutaneous nerve, which was divided at the elbow and sutured to the sensory branch of the radial nerve. The radial nerve was then sutured to the median nerve in the lower part of the forearm. The follow-up is not long enough to evaluate the result.

Histochemical Studies on Glycogen in Normal Ossification and Calcification

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INTRODUCTION

Knowledge of the structure and chemical composition of bone and cartilage, containing mainly carbohydrates in the form of polysaccharides, generally combined with proteins, has greatly increased in recent years; however, the intimate mechanism of the metabolic and secretory processes which take place during the formation of bone tissue is still not completely understood. In spite of investigations with the electron and phase microscope, and the introduction of radioactive isotopes in the study of histophysiology, many points are still obscure in the formation of fundamental mucoprotein substances, especially the exact mechanism of calcium precipitation. There is strong evidence that the enzyme, alkaline phosphatase, is concerned with the formation of bone and the calcification of cartilage, but not with the development of the mucoprotein cartilage matrix in normal and pathological conditions [21, 22]. However, it is not definite whether alkaline phosphatase acts only on the formation of organic bone matrix, or if it also produces chemical changes which prepare it for its calcification; glycogen and some enzymes such as phosphorylase or trans-phosphorylase [10, 11, 12, 13] which are present in great quantities in cartilage undergoing calcification may play an intermediary role. Glycogen disappears abruptly when calcification occurs. The role of glycogen in osteogenesis is not definite and its cytohistochemical localization has been reported recently with differing results [1, 3, 5, 16, 20, 21, 24].

Bevelander and Johnson found considerable amounts of glycogen associated with areas of membranous-bone formation in pigs. At first it is widely distributed in the undifferentiated mesenchymal tissue. With the incidence of a definite spicule anlage, wherein osteoblasts appear to be differentiated, these cells momentarily lose their glycogen. This condition persists until just before mineralization. When mineralization occurs both osteoblasts and osteocytes attain a maximum glycogen content. Except for a brief phase in development, glycogen is abundantly present in periosteum, osteoblasts, and osteocytes throughout the stages of development and calcification. Follis [5] mentioned that the osteoblasts contain glycogen in the cytoplasm.

Nevertheless, Pritchard, while studying developing membrane bones in the rat, found an abundance of glycogen in the differentiating osteoblasts (pre-osteoblasts), but complete absence of glycogen in active osteoblasts. Small amounts of glycogen appeared in less active and resting osteoblasts in more mature bone.

Heller-Steinberg found Hotchkiss-stainable granules (not digestible by ptyalin, that is to say not glycogen) in osteocytes and osteoblasts related to the functional activity of these cells. Normally they were present throughout most of the bone cells of the metaphysis, a region of rapid bone turnover. She found these granules present in the osteoblasts when bone was forming but absent when the osteoblasts assumed a spindle form or were being transformed from spindle cells to osteoblasts. They were not evident in the bone cells of the diaphysis, a relatively quiescent portion of the bone, although, in this zone only, osteocytes rich in glyco-

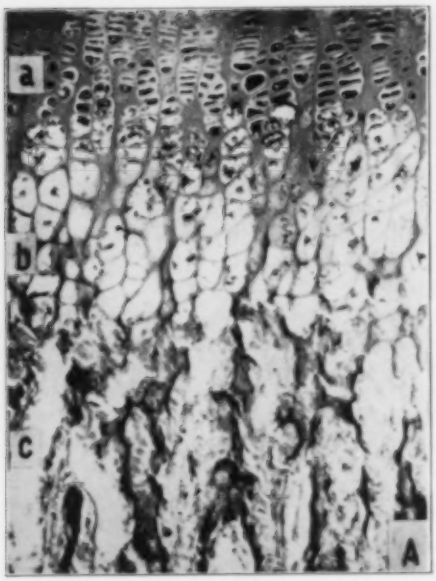

FIG. 1-A

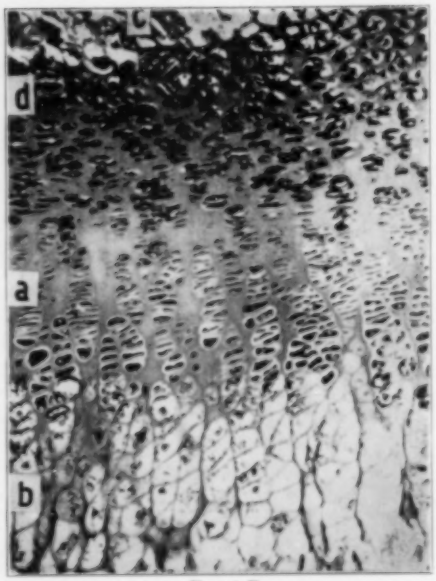

FIG. 1-B

Figs. 1-A and 1-B: Photomicrographs (× 190) showing endochondral ossification in the femur of a seven-day-old rat treated with McManus' stain without nuclear counterstain.

Fig. 1-A: Proliferating cartilage, *a*, rich in glycogen granules in the cell cytoplasm is seen and, *b*, hypertrophic and calcified cartilage shows loss of glycogen which completely disappeared in the lower part of this zone. In *c*, bone trabeculae are in formation; there is no glycogen in the rows of osteoblasts, but a few granules in neighboring mesenchymal cells are seen.

Fig. 1-B: *a* and *b* are the same as in Fig. 1-A; the epiphyseal ossification center can be seen, *c*. The cartilage cells around it are full of glycogen granules (*d*).

gen were found. She considered the possibility that the Hotchkiss-stainable granules would represent a precursory secretion of the bone ground substance as observed in the fibroblasts. Nevertheless the finding of identical Hotchkiss-stainable granules in the osteoclasts (the indicators of bone resorption) would not be in agreement with this interpretation. Jackson and Smith confirmed the presence of cytoplasmic periodic acid-Schiff positive granules in the osteoblasts (*in vivo* and *in vitro*). McLean and Urist only transcribe the conclusion reached by Heller-Steinberg.

Cobb described the presence of phosphorylase in a diffuse form in the cytoplasm of osteoblasts and osteocytes of bone spicules, including those most recently formed. The osteocytes and osteoblasts of the bone trabeculae neighboring the epiphyseal cartilage, the only region she studied, have little or no glycogen.

In an earlier paper [21] in which we analyzed the histochemical behavior of alkaline phosphatase, glycogen, and mucopolysaccharides in bone and cartilage under normal and pathological conditions, we were not able to come to any definite conclusions about the behavior of glycogen in the formation of normal and pathological bone. Its presence appeared inconstant and its distribution irregular.

In view of the divergent views obtained in investigations done with modern histochemical techniques on the behavior of glycogen in normal osteogenesis, we think it opportune to continue our study under the best possible technical conditions. We have tried to determine the influence of the different types of decalcifying agents and fixatives on the histochemical detection of glycogen [23].

Cartilaginous tumors possess a distribution of glycogen similar to that of hyaline and normal growth cartilage; the degenerative and necrotic zones lack glycogen. Its behavior is irregular in malignant tumors (Figs. 4-A and 4-B). In direct pathological ossification (tumorous, dystrophic, and reactional), glycogen seems to

repeat the cycle found in direct normal osteogenesis. In osteogenic sarcoma, the distribution of glycogen is very irregular (Figs. 5-A, 5-B, 6-A, and 6-B). Glycogen does not intervene in cases of heterotopic calcification. In a subsequent paper we plan to discuss these pathological conditions in detail.

MATERIALS AND METHODS

For normal material, zones of ossification from the heads, vertebrae, ribs, and extremities of stock mice and stock rats, aged five days, fifteen days, and one month, were used. Areas of endochondral growth of the lower extremities, vertebrae, and phalanges of human foetuses and newborn infants were also used.

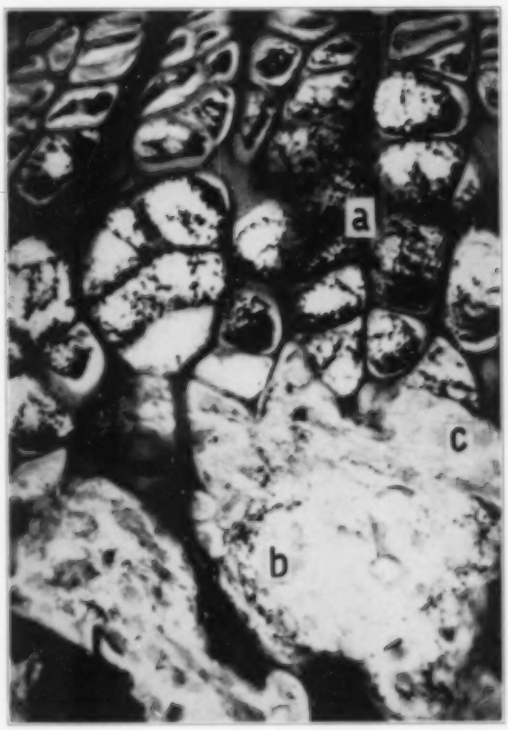

FIG. 2

Endochondral ossification in the vertebra of a seven-day-old rat. The cartilage cells, *a*, of the hypertrophic and calcified zone have abundant glycogen granules. Glycogen is seen also in the mesenchymal cells (*b*) near the osteoblasts covering the bone surface, *c*, of calcified cartilage cores. McManus' stain without nuclear counterstain (× 340).

Each specimen was fixed in 80 per cent alcohol, absolute alcohol, methyl alcohol, Zenker-formol fixative, osmic acid, and Rossman's fluid, with or without previous vascular injections of Orth's fluid according to the instructions of Shimizu and Kumamoto [26]. Fixation was also done by the Altmann-Gersh method (freezing at —78 degrees centigrade and —160 degrees centigrade and dehydration at —40 degrees centigrade), followed by denaturation with absolute alcohol. The best fixation of glycogen was obtained by the Altmann-Gersh method and with Rossman's fluid. The results by these two techniques were nearly identical; 80 per cent alcohol and absolute alcohol provided fairly reliable fixation although the results varied. Shimizu's technique showed no advantage in the conservation of glycogen in the ossification centers.

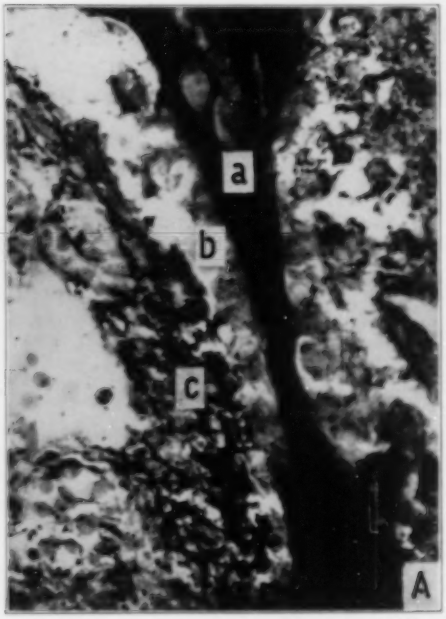

FIG. 2-A

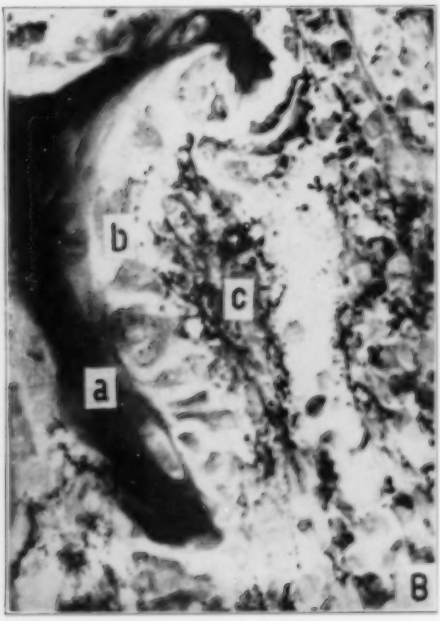

FIG. 3-B

Direct membranous ossification in the head of a rat, seven days old. Bone trabeculae (*a*) are surrounded by rows of hypertrophic osteoblasts (*b*) almost completely free of glycogen granules. On the contrary, the neighboring mesenchymal cells (*c*) have abundant glycogen. McManus' stain without nuclear counterstain (× 340).

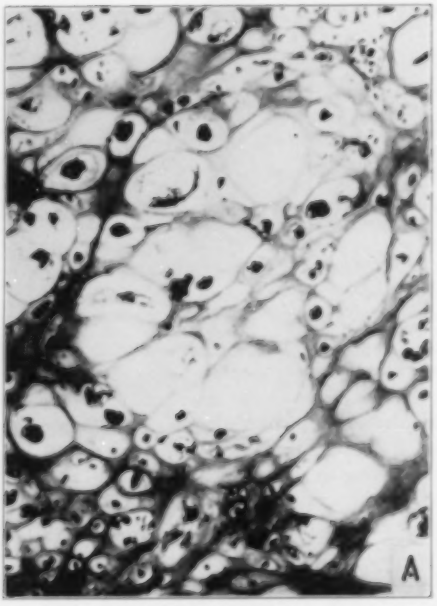

FIG. 4-A

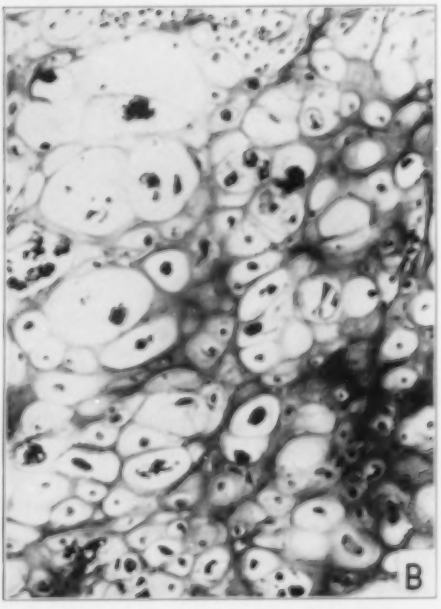

FIG. 4-B

Chondrosarcoma of the femur, showing the irregular size, form, and distribution of the cartilage cells and the cytoplasmic glycogen which is abundant in viable, and absent in necrobiotic, zones. McManus' stain without nuclear counterstain (× 580).

FIG. 5-A

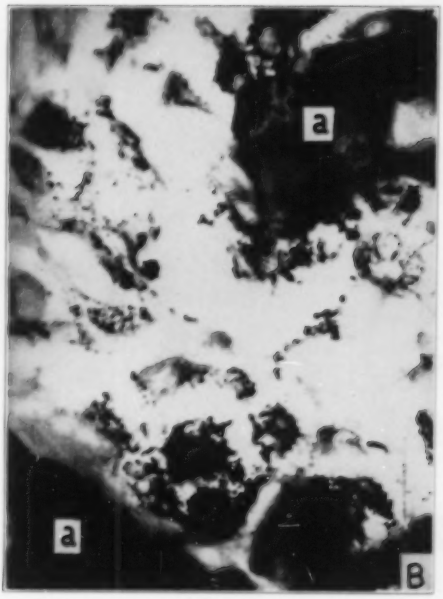

FIG. 5-B

Osteogenic sarcoma, sclerosing type, of the lower femoral metaphysis. Newly formed tumorous bone trabeculae (*a*) are surrounded by atypical osteoblasts generally full of glycogen and irregularly distributed. McManus' stain without nuclear counterstain (× 580).

The glycogen was colored with periodic acid-Schiff according to the McManus and Hotchkiss method and the modified method suggested by Shimizu (oxidation with lead tetra-acetate instead of periodic acid). For identification, enzymatic digestions were made in every case with taka-diastase for fifteen to thirty minutes at room temperature and with ptyalin for one to three hours at 37 degrees centigrade.

The pathological material used was fixed in 80 per cent alcohol and with Rossman's fluid. Fixations were obtained which gave results almost as good as those obtained by the Altmann-Gersh method which is difficult to carry out with this type of material.

In no case did we use decalcified material, since all media of decalcification produce relatively intense changes in the cytoplasmic glycogen, making it difficult to use this material for histochemical investigations [23]. Lately, we have observed that Rossman's fluid can be used as a weak decalcifier without appreciable loss of glycogen. In each case the phosphatase activity was studied by Gomori's technique, with different periods of incubation being used in order to evaluate the different intensities of enzymatic activity.

RESULTS

Endochondral Ossification

In this type of ossification there is a cartilaginous stage before the formation of bone trabeculae. Cartilage habitually contains glycogen in all its cells, except in the peripheral areas of perichondral growth and the tangential layer of articular cartilage. In the proliferating area of the growth cartilage, the cells increase in size, especially when they approach the area of hypertrophic cartilage. This increase in the size of the cells is accompanied by an increase in the quantity of glycogen granules, there being no increase in the concentration per unit of cytoplasmic volume. In some cases, there is a slight decrease in glycogen granules due

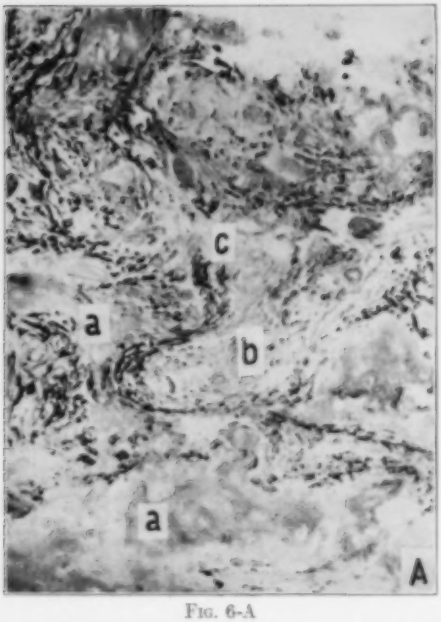

FIG. 6-A

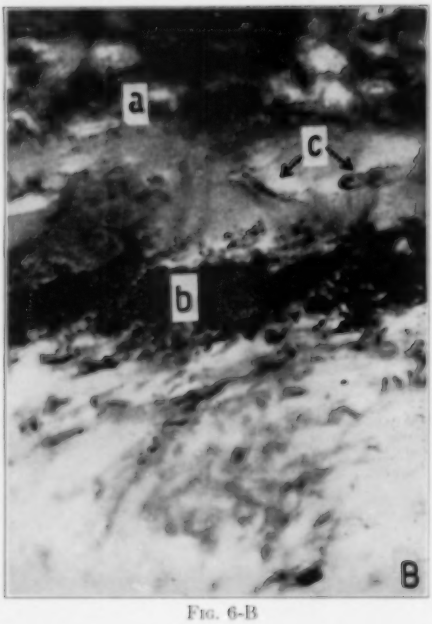

FIG. 6-B

Figs. 6-A and 6-B: Fibrous dysplasia of the humerus.

Fig. 6-A: At low magnification, this photomicrograph shows newly formed, partially calcified bone trabeculae (*a*) separated by fibrous marrow (*b*). These trabeculae are surrounded by rows of flattened osteoblasts (*c*) full of glycogen, and by some hypertrophic osteoblasts without glycogen. McManus' stain without nuclear counterstain (× 190).

Fig. 6-B: Centrally calcified bone trabeculae (*a*) surrounded by flattened osteoblasts (*b*) rich in glycogen are seen. A zone of the neighboring mesenchymal cells also contain abundant glycogen. Some younger osteocytes (*c*) have a few glycogen granules. McManus' stain without nuclear counterstain (× 680).

to the abundance of hydropic vacuoles in some cells in the area. The behavior described so far is the same for all types of endochondral growth, but we must distinguish between three rates of growth: slow, moderate, and rapid.

When growth is rapid, as in the epiphyseal cartilage at the lower end of the femur (Figs. 1-A and 1-B) and at the upper end of the tibia of young rats, a wide band of hypertrophic and proliferating cartilage is seen. Glycogen disappears abruptly as the hypertrophic cartilage becomes calcified, and, in the last rows of calcified hypertrophic cartilage, glycogen is generally absent. In instances of moderate growth (Figs. 1-B and 2), as in the epiphyseal ossification center and in the border between the vertebrae and intervertebral discs of rats of the same age, the disappearance of glycogen is not constant. In these cases, hypertrophic cartilaginous cells undergoing calcification, or already calcified, almost bordering the line of erosion, maintain frequently a small quantity of glycogen. Where the endochondral growth is very slow, as in subchondral articular zones, it is impossible to detect any decrease in the glycogen content, even in calcified cartilage.

The distribution of glycogen also varies according to the rate of growth in the zones of primary osseous trabeculae which form immediately beneath the zone of cartilaginous erosion. In cases of rapid growth (Fig. 1-A), there is no glycogen present or only a few isolated granules are found, usually in the mesenchymal cells of the bone marrow near the newly formed bone trabeculae. When endochondral proliferation is moderate (Fig. 2), glycogen is frequently found in the mesenchymal cells bordering the rows of usually hypertrophic osteoblasts. Sometimes extracellular or intracellular granular deposits are found in the areas near the line of erosion in direct relationship to the cartilaginous capsules destroyed during the process of endochondral ossification, the cells of which have not experienced the

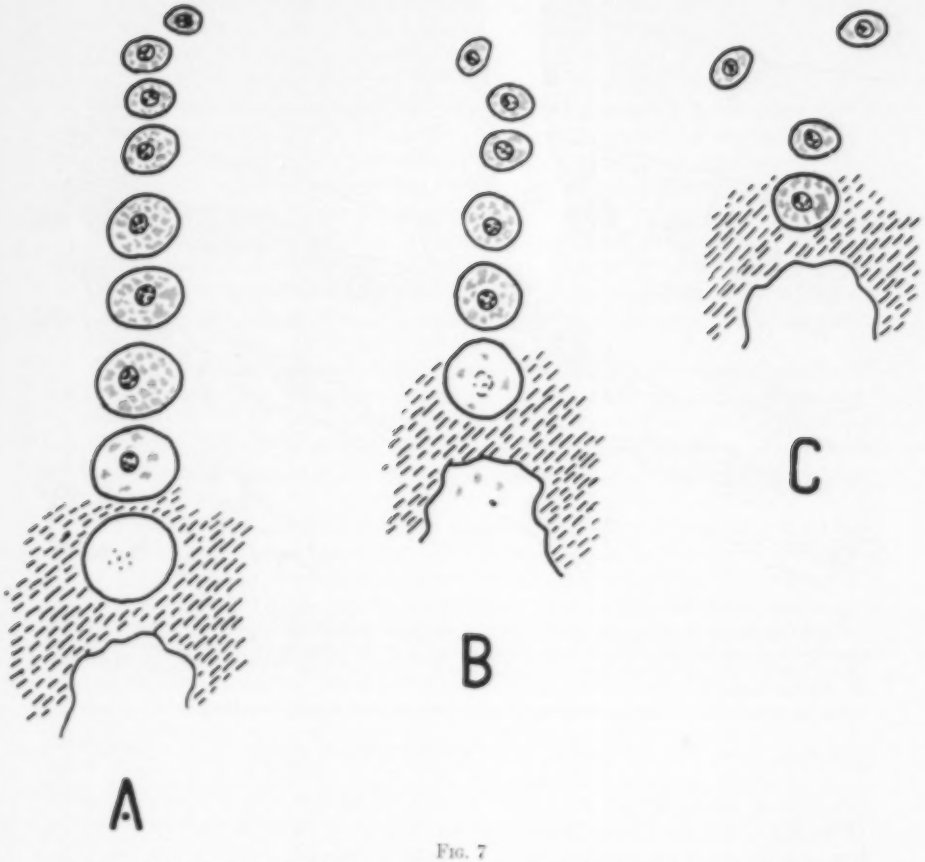

FIG. 7

Schematic drawing shows the distribution of glycogen (shaded areas) in cartilage cells of the epiphyseal cartilaginous plate in relation to the speed of growth: *A*, rapid; *B*, moderate; and *C*, slow.

usual fall in glycogen. Abundant glycogen is regularly found in all osteoblasts surrounding the subchondral trabeculae during slow growth. The osteoblasts are flattened and we believe they have little activity.

The findings described were consistent in both rats and mice. We cannot give definite conclusions on our studies in man. Although we think that the conclusions from study of human material would agree with those gained from our study of animal material, our subjects were limited mainly to pathological foetuses and newborn infants.

Direct or Membranous Ossification

The undifferentiated mesenchymal cells do not generally contain glycogen. When this substance appears it indicates, in our opinion, the first stage of differentiation (myoblastic, osteoblastic, myxoid, cartilaginous, and lipoblastic). Therefore when a bone trabecula is formed in the center of an undifferentiated mesenchyma, the first thing observed, besides the known morphological changes, is the appearance of large quantities of glycogen granules in the cells which will later differentiate into osteoblasts (pre-osteoblasts). Later when the deposit of osteoid material commences, two conditions are established according to the velocity of osteogenesis. In those bones where there is active formation, the osteoblastic cells are arranged in rows; they are hypertrophic, of an epithelioid aspect, and possess

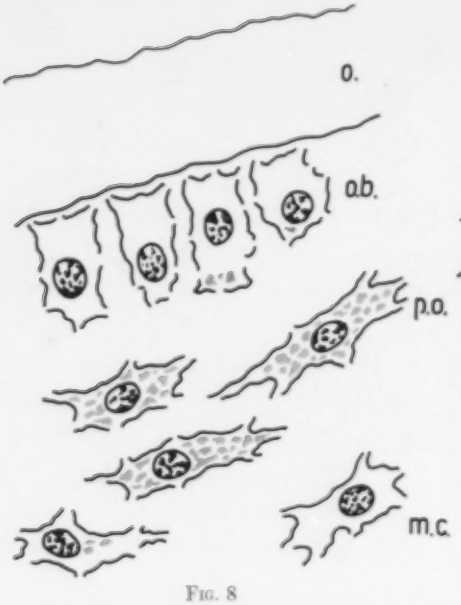

FIG. 8

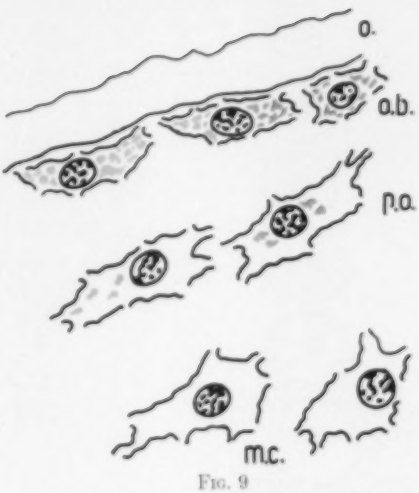

FIG. 9

Fig. 8: Drawing showing the distribution of glycogen granules in a region of active direct membranous ossification. Osteoid bone is represented on the drawing by *o.*; hypertrophic active osteoblasts, by *o.b.*; pre-osteoblasts, by *p.o.*; mesenchymal cells, by *m.c.*; and glycogen granules, by shaded areas.

Fig. 9: Direct membranous ossification in a zone of slow bone formation.

abundant basophilic cytoplasm, polarized toward the surface of the trabeculae. They generally contain no glycogen, or only small quantities of glycogen, while neighboring mesenchymal cells show cytoplasm replete with glycogen granules (Figs. 3-A and 3-B). This histochemical distribution is not in relation to the initiation or progress of the calcification of the bone trabeculae. Nevertheless, the cytoplasm of the osteoblasts gave a weak, diffuse periodic acid-Schiff positive reaction, superimposed on the areas of intense basophilia. When the bone trabeculae are formed slowly, the flattened, slightly active osteoblasts generally contain abundant granules in their cytoplasm. Our findings concerning the behavior of glycogen in direct ossification agree in man and in the animals investigated.

Resting Bone

By resting bone, we mean those areas in which no histological signs of apposition or reabsorption on the surface of the laminar bone trabeculae are observed. These areas are found without osteoid border and osteoclastic elements, it being possible to find some flattened cells (inactive osteoblasts) on the trabecular surface.

It is difficult to obtain good sections of this material, since it is usually necessary to decalcify the sections beforehand. As we have said before, decalcification causes changes which make the histochemical investigation of glycogen difficult.

Glycogen is scarce in these areas and in some cases can only be seen in the cytoplasm of the flattened osteoblastic cells. We believe that these cells are slightly richer in glycogen in the hematopoietic marrow than in the yellow marrow. On the other hand in the hematopoietic marrow, glycogen is found in cells in granulocytic differentiation. The histiocytes of the reticulum and the cells issuing from the erythroblastic progeny do not contain glycogen. In the cytoplasm of the megakaryocytes, there is periodic acid-Shiff positive material which is not eliminated during ptyalin digestion.

Using Rossman's fluid as a decalcifying agent, we sometimes found in the osteocytes of laminar mature bone trabeculae glycogen granules.

DISCUSSION

As the result of our investigations, we found that glycogen is a substance which appears to play an important role in the process of direct and endochondral ossification. Histochemically, we were able to detect the presence of glycogen in those areas where the bone had formed, either with or without cartilaginous intervention, although the behavior of glycogen varied in each case.

We also found a regional distribution of this substance in rats which varied in relation to the speed of direct or endochondral ossification (Figs. 7, 8, and 9). This distribution appeared to be repeated in other animals studied (mice, chickens, and dogs) and also in man, although the number of cases studied is too small to enable us to draw any definite conclusions.

The sudden disappearance of glycogen in the cartilage during the process of calcification has been recognized for many years [8] and has been confirmed in recent papers [6, 7, 9, 15, 17]. Together with the identification of phosphorylase enzymes [3, 11] in the area of endochondral ossification, the disappearance of glycogen during calcification has been the basis of a new biochemical interpretation of the process of calcification [13].

We confirmed this fall of glycogen in the epiphyseal cartilage of young rats during active growth, and found the fall of glycogen to be more evident in the actively growing lower femoral and upper tibial epiphyses (Figs. 1-A and 1-B). Nevertheless, the fall of glycogen did not occur when growth was slow, for example, in the epiphyseal centers where the cartilage becomes calcified, a decrease of glycogen in the hypertrophic chondrocytes was not observed (Fig. 2). On the other hand, in the sites of moderate growth, even when there was a decrease in glycogen, which was neither extensive nor complete, a small quantity of this polysaccharide was observed in the majority of the hypertrophic cells of the calcified area in erosion. Because of the persistence of glycogen in this area, free granules were found in nearby bone marrow, the result of the opening of cartilaginous capsules during the process of vascular-chondroclastic penetration. The dissimilar histochemical behavior, in accordance with the rate of growth, makes it difficult to accept freely Gutman's hypothesis, where the fundamental principle is the sudden fall of glycogen.

While the histochemical distribution of glycogen in the growth cartilage is constant in the different species of animals studied, it is less constant in the subchondral region where bone formation is produced on the basis of the calcified cartilaginous cores.

There appears to be a relationship with the rate of growth here, and it was observed that in cases of rapid growth there is either a complete absence of glycogen granules in the mesenchymal cells neighboring the subchondral trabeculae, or only a few isolated granules present (Fig. 1-A). In the sites that grow moderately fast, glycogen granules appear to be localized especially in the mesenchymal cells near the osteoblasts where there may also be a few granules (Fig. 2). When growth is very slow, rows of atypical flattened osteoblasts are found, their cytoplasm being loaded with glycogen. This distribution has not yet been analyzed by writers who have studied this subject [3, 16]; in some ways it is similar to the process occurring in direct (membranous) ossification.

In direct ossification, we also found a close relationship between the distribution of glycogen and the speed of growth. When active and hypertrophic osteoblasts were found in epithelioid rows, they generally did not contain glycogen, or at most there were a few granules (Fig. 8). These granules were present in large quantities in neighboring mesenchymal cells (pre-osteoblasts). This, thus, resembles a fall of glycogen in rapidly growing cartilage. However, when the trabeculae are formed slowly, the flattened, slightly active

osteoblasts generally contain abundant glycogen granules in their cytoplasm (Fig. 9).

Our findings concerning membranous ossification coincide with those of Harris who found glycogen in the pre-osseous mesenchymal cells and stated that it was absent in active osteoblasts on the surface of the bone matrix. Pritchard, using modern histochemical methods on rats, also confirmed the abundance of glycogen in the differentiating osteoblast but found its complete absence in active osteoblasts of membrane bone. The absence of glycogen was also observed in the periosteum of developing long bone. However, Bevelander and Johnson found that, except for a brief phase in development, glycogen was abundant in periosteum, osteoblasts, and osteocytes in pigs. Follis and Berthrong described the presence of glycogen in active osteoblasts and osteocytes, and Follis [4] described the disappearance of glycogen in experimental scurvy and its rapid reappearance when vitamin C was administered.

The behavior of glycogen in fracture callus is similar to its behavior in membranous ossification [25] contrary to the findings of Pritchard who reported no glycogen in either differentiating or mature osteoblasts and only minimal quantities in resting osteoblasts and osteocytes.

We have not been able to demonstrate the presence of Hotchkiss-stainable granules, not digestible by ptyalin, which are present, according to Heller-Steinberg, throughout most of the bone cells in active function in the metaphyseal region but absent when the osteoblast assumes the spindle form or in the diaphysis, a relatively quiescent portion of bone. Similar granules have been found by Jackson and Smith *in vitro* and *in vivo* in fibroblasts and in osteoblasts which were present mainly when intercellular material was about to be, or was being, deposited. Their deposition was in relation to their production. The cytochemical observations of positive reactions with the periodic acid-Shiff and Hale technique, the presence of metachromasia and the property of a pH of about 7 taken together, would indicate that the granules of osteoblasts in tissue culture contain, at least in part, an aminopolysaccharide. It is remarkable that Jackson and Smith do not mention the existence of glycogen granules in mesenchymal cells in osteoblastic differentiation or in the osteoblasts which are so easily demonstrated in material that has been correctly fixed and which has been described in different ways by all authors who have written on this subject.

In conclusion, we can state that glycogen is present in endochondral and membranous ossification in determined locations and distribution. The distribution is in close relationship with the speed of this process.

We still have to determine the significance of the unique histochemical distribution of glycogen. Gutman [10] presented a theory concerning the calcification of cartilage, basing it on the fall of glycogen in the hypertrophic epiphyseal cartilage undergoing calcification and the presence of glycogenolytic enzymes such as phosphorylase and trans-phosphorylase. It is necessary to emphasize that Gutman's hypothesis concerns only calcification of growth cartilage while we have been able to show that it is applicable only to rapidly growing epiphyseal cartilage, in which this sudden drop in glycogen occurs simultaneously with calcification. Ham nevertheless considered the decrease and disappearance of glycogen in the calcification zone to be simply a phase in the autolysis of dying cells.

The presence of glycogen granules in the mesenchymal cells in osteoblastic differentiation and its disappearance in hypertrophic osteoblasts during direct rapid ossification appear to be reasons for extending Gutman's hypothesis to the calcium precipitation in bone matrix; nevertheless, the almost complete absence of glycogen in areas of subchondral ossification (under the epiphyseal cartilage in rapid growth), and the presence of grains of glycogen in osteoblasts during slow direct bone formation, are obstacles which prevent us from entirely accepting Gutman's hypothesis. These two facts also oppose Pritchard's opinion which, apparently based on Brachet's studies, was that the presence of glycogen in pre-

osteoblasts merely indicated a general biochemical adaptation of the conditions of embryonic life and has no specific significance in bone formation.

It is possible that glycogen intervenes in the formation of substances which are later used by osteoblasts for the production of proteins and mucoproteins of osteoid matrix, or they act as a source of energy.

CONCLUSIONS

1. Normal hyaline cartilage contains glycogen in all its cells, with the exception of the peripheral growth zones and the tangential layer of the articular cartilage.

2. In growing epiphyseal cartilage the behavior of glycogen differs according to the rate of growth. The increase of glycogen is constant in hypertrophic cartilage; however, it disappears completely if growth is fast, partially if growth is moderate, or remains if growth is slow.

3. Glycogen is usually scarce in areas of primary bone trabeculae in the subchondral layer of endochondral ossification, except in parts where growth is slow and glycogen is found in moderate quantities.

4. Glycogen is constantly present in direct or membranous ossification; its distribution varies according to the speed of osteogenesis.

5. In areas of active osteogenesis, the hypertrophic osteoblasts contain little or no glycogen, while the adjacent mesenchymal cells (pre-osteoblasts) contain a moderate to abundant quantity of glycogen granules. The flattened atrophic osteoblasts on the surface of slowly growing bone trabeculae contain abundant glycogen. The osteocytes in both of these conditions usually lack glycogen.

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Fracture Healing in Rats Treated with Aminoacetonitrile*

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The extensive derangement of the mesodermal tissues in vertebrates, caused by the administration of aminonitriles, has been widely studied [7]. The aminonitriles affect a definitely limited stage of the process of mesodermal-tissue differentiation, and early embryonary development is little disturbed. For example, aminonitriles administered to pregnant rats did not harm the foetus until after the sixteenth day of gestation [9]; low doses of β-aminopropionitrile injected into incubating hen's eggs caused no harmful effects until the thirteenth day of incubation when a bending of the femur appeared [2]; weak solution of β-aminopropionitrile were without effect in larvae of the South African toad until shortly before metamorphosis when severe limb deformities occurred [2]. On the other hand, mature animals also are resistant to the aminonitriles; slight skeletal deformities or degenerative joint disease may develop only after prolonged treatment [4].

The proliferative zone of the epiphyseal plate of young mammals is particularly vulnerable to the action of the aminonitriles [4]. Cellular proliferation is not impaired, but rather the ground substance appears to be defective [1]. The developing fibrous-connective tissue in healing wounds in the mature animal is also affected by these compounds [3]. In the same manner, the regenerating limbs of adult newts are severely affected by the aminonitriles [4]. Bone is one of the tissues in which repair simulates growth in its physiological and morphological processes. The experiments reported demonstrate that fracture healing in adult rats also is greatly altered by the aminonitriles. In a previous paper, it was reported that low doses of l-triiodothyronine suppressed the mild forms of aminoacetonitrile poisoning in young rats [5]. The effect of l-triiodothyronine on fracture healing in adult rats fed aminonitriles will be reported.

METHODS

Forty-five adult male Sprague-Dawley rats, weighing 230 to 260 grams, were housed in cages in groups of nine. A fracture in the middle third of the left forearm bones was produced manually in every rat under ether anaesthesia by bending the forearm over the dull edge of a large knife held in a vise. The fractures were not immobilized. Group 1 was fed Purina chow and served as control. Group 2 was fed ground Purina chow containing 0.075 per cent aminoacetonitrile** during the entire experiment. Group 3 received the same diet as the second group for the first week only, after which the diet was changed to Purina chow alone for the remainder of the experiment. Group 4 received ground Purina chow containing 0.1 milligram l-triiodothyronine per 100 milligrams chow, and Group 5 received ground Purina chow containing 0.075 milligram aminoacetonitrile and 0.1 milligram l-triiodothyronine per 100 milligrams chow. All diets were fed *ad libitum*. Roentgenograms of the rats under ether anaesthesia were made every week. Three animals of every group were sacrificed

*Aided by Grant A-149 from the National Institutes of Health, United States Public Health Service.

**Given in salt form, aminoacetonitrile sulphate.

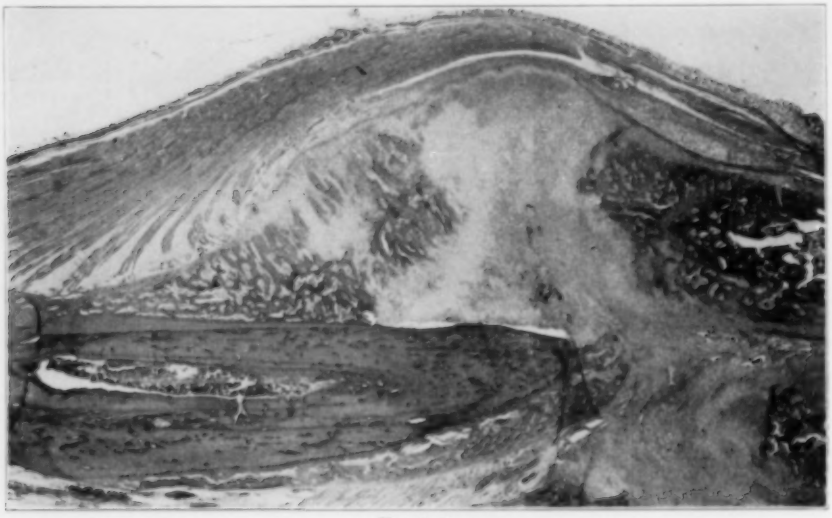

FIG. 1-A

Photomicrograph (×9) of one-week-old fracture of the radius in a rat of Group 1 (normal control). Periosteal new bone is deposited on each side of the fracture line where a large fibrocartilaginous callus containing some bone debris is observed.

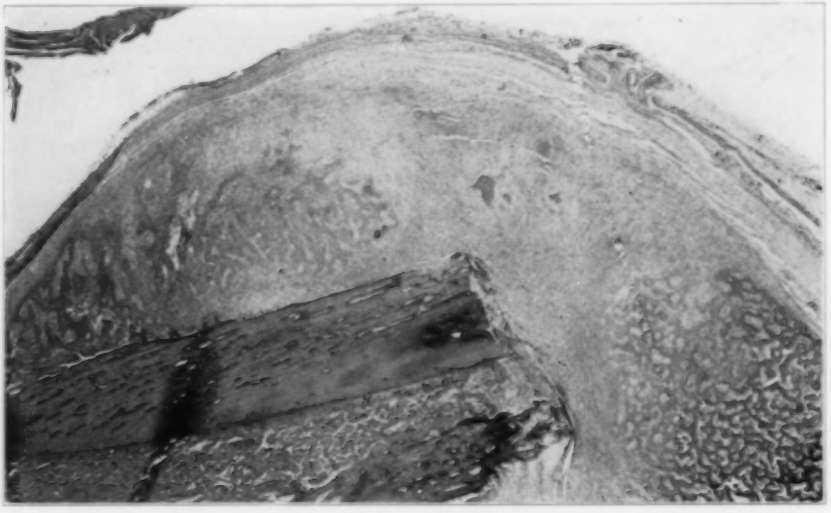

FIG. 1-B

Photomicrograph (×9) of one-week-old fracture of the radius in a rat of Group 2 (treated with aminoacetonitrile). Periosteal osteogenesis is very abundant and the fibrocartilaginous callus is more voluminous than that in Fig. 1-A.

at the end of the first week, three more at the end of the second week, and the remaining three were sacrificed at the end of the third week. The fractured extremities were amputated, fixed in formalin, decalcified in a 6 per cent aqueous solution of sulphosalicylic acid, and embedded in paraffin. Care was taken in obtaining longitudinal sections of both forearm bones from the blocks. Hematoxylin and eosin, Mallory, and Laidlaw silver carbonate stains were used.

RESULTS

No gross abnormalities were observed in any of the rats during the experi-

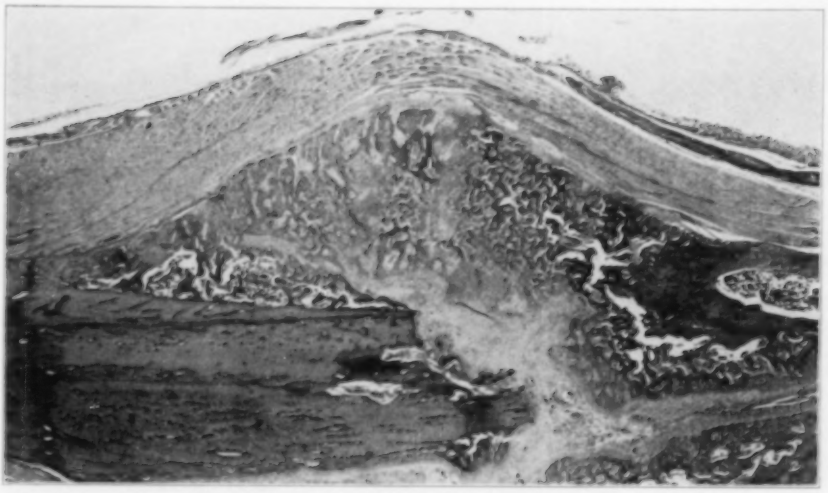

FIG. 2-A

Photomicrograph (×8.5) of a two-week-old fracture of the radius in a rat of Group 1 (normal control). Periosteal and enchondral new bone bridge the fracture line. Some fibrocartilaginous callus remains between the bone fragments.

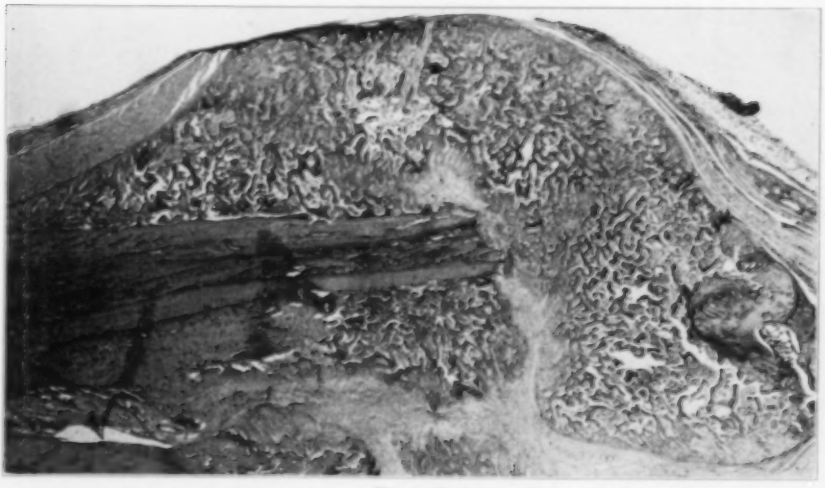

FIG. 2-B

Photomicrograph (×8.5) of a two-week-old fracture of the radius in a rat of Group 2 (treated with aminoacetonitrile). Bone trabeculae form a giant callus bridging the fracture line. A small band of fibrous tissue remains to be ossified.

ment; the animals gained from ten to thirty-two grams in weight, irrespective of treatment.

At One Week

The roentgenograms obtained one week after fracture revealed a very slight amount of ossification in the callus; no clear differences were observed among the five groups.

The histological sections demonstrated the following:

Group 1: A well developed fibrocartilaginous callus was present with hyaline cartilage well organized in areas close to the lifted periosteum. Enchondral bone was beginning to form. Small fragments of necrotic bone in the callus were in

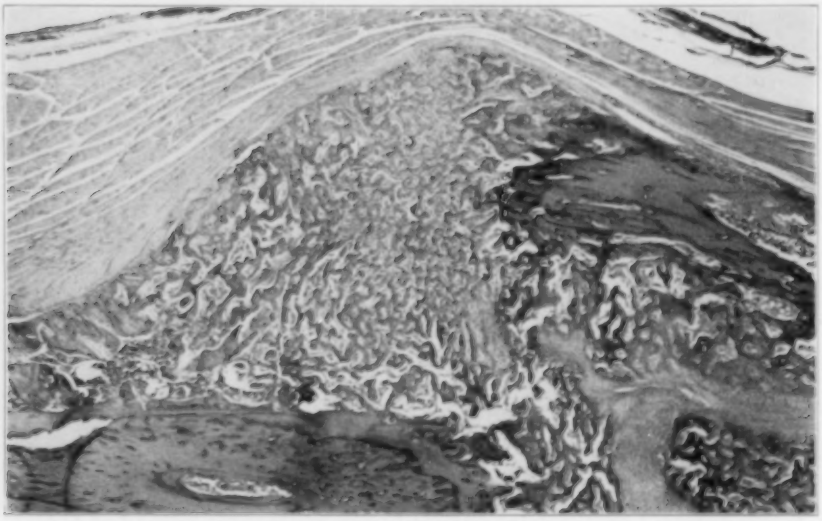

FIG. 3-A

Photomicrograph (×11.5) of a three-week-old fracture of the radius in a rat of Group 1 (normal control). Bone union of the fracture is completed.

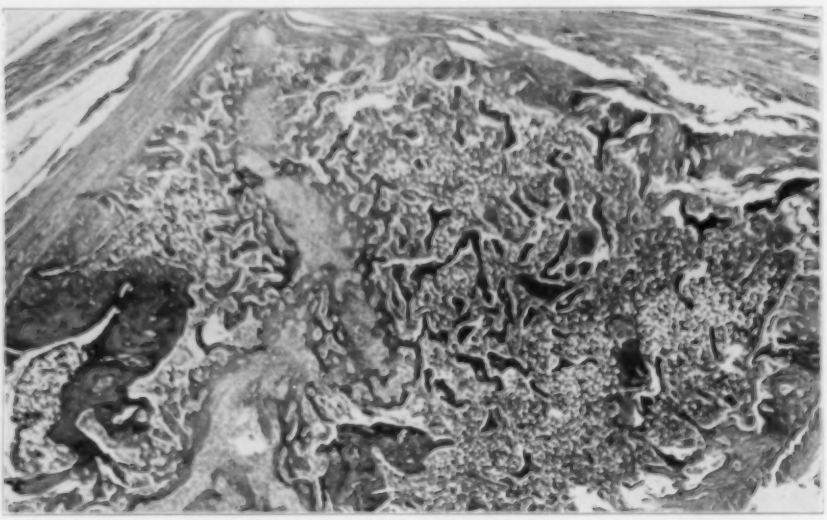

FIG. 3-B

Photomicrograph (×11.5) of a three-week-old fracture of the radius in a rat of Group 2 (treated with aminoacetonitrile). Few bone trabeculae are seen in the large callus and fatty marrow is abundant. A zone of fibrous tissue crosses the callus.

the process of being reabsorbed. Intramembranous-bone formation was prominent on each side of the fracture line (Fig. 1-A).

Group 2: The fibrocartilaginous callus was much more voluminous and less well organized than that in the control animals. Areas of immature hyaline cartilage cells were interspersed in a loose and very cellular fibroblastic tissue. The collagen fibers were small, wavy, and frail. Abundant and apparently normal intramembranous bone had formed on each side of the fracture line (Fig. 1-B).

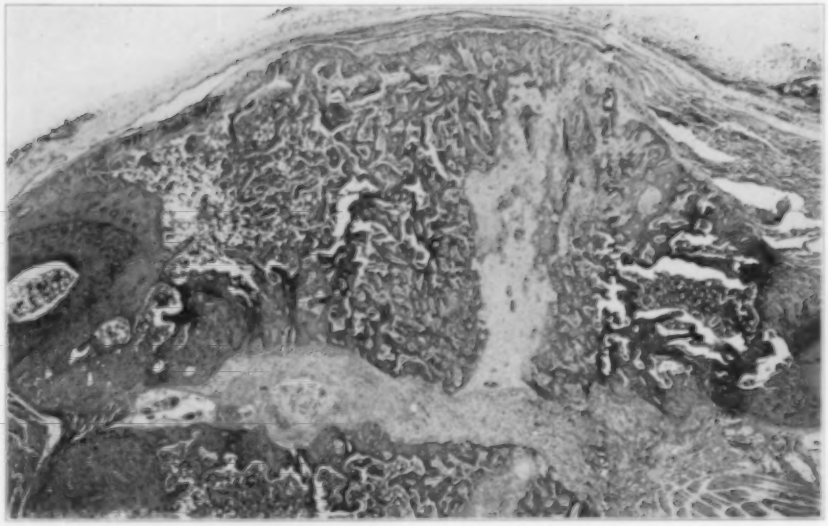

FIG. 3-C

Photomicrograph (×11.5) of a three-week-old fracture of the radius in a rat of Group 5 (treated with aminoacetonitrile and l-triiodothyronine). New bone trabeculae are more abundant than in that shown in Fig. 5-B. A wide zone of fibrocartilaginous callus is seen across the callus.

Group 3: Sections were similar to those of Group 2.

Group 4: No differences could be observed between this group and Group 1.

Group 5: The size of the fibrocartilaginous callus was similar to that of Groups 2 and 3. However, in Group 5, the ground substance appeared less granular, the collagen fibers were thicker, and the cartilage cells were more mature and better bound than they were in Groups 2 and 3.

At Two Weeks

Group 1: The roentgenograms revealed a well developed periosteal callus with no evidence of bone union (Fig. 5-A).

The histological sections demonstrated extensive areas of intramembranous and enchondral-bone formation in the fracture callus. Bone union was almost complete at the periphery of the callus. Fibrous-connective tissue and fibrocartilage were still prevalent between the bone ends (Fig. 2-A).

Group 2: A very large and irregularly ossified callus was observed in the roentgenograms with bone union present in two of the six remaining rats in this group (Fig. 5-B).

On histological examination, the periosteal and enchondral new bone was very extensive, forming a giant callus. The new bone trabeculae were wide and well ossified, although some osteoid was present at the margins of the trabeculae. The enchondral-bone formation was not proceeding in as orderly a fashion as that in the control animals. In some areas, the cartilage cells were very large with irregular, hyperchromatic nuclei resembling the cells of chondrosarcoma. A small amount of very cellular fibrous-connective tissue was present between the bone ends. Bone union was almost complete (Fig. 2-B).

Group 3: The roentgenograms demonstrated a large and well ossified fracture callus with well established bone union in four of the six remaining animals (Fig. 5-C).

The histological sections revealed a callus larger than those of Group 1 and not as large as those of Group 2. The intramembranous-bone formation was extensive, and the bone trabeculae were wide and well ossified. The enchondral

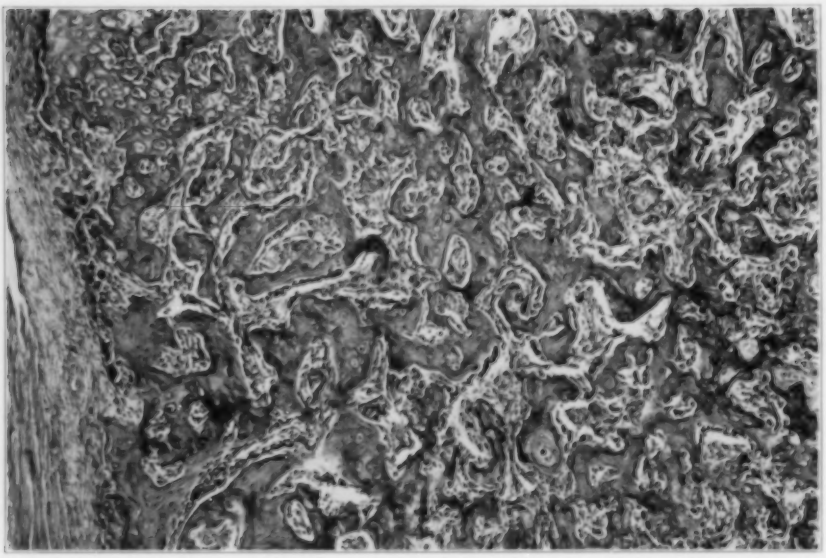

FIG. 4-A

Photomicrograph (×105) of a peripheral area in the callus of Fig. 3-A (Group 1) showing dense and well ossified bone trabeculae.

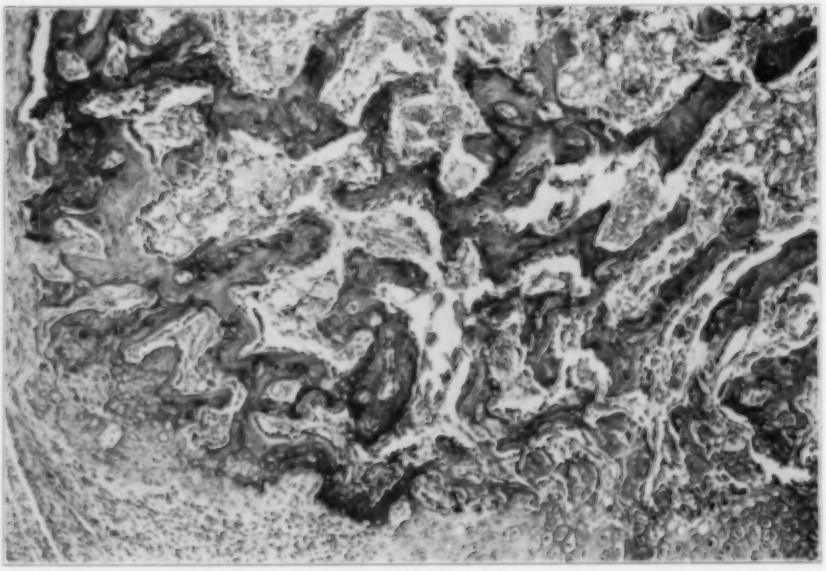

FIG. 4-B

Photomicrograph (×105) of a peripheral area in the callus of Fig. 3-B (Group 2) showing thin and sparse bone trabeculae and wide, vascular marrow spaces.

ossification was proceeding normally, and only a small zone of non-ossified fibro-cartilaginous callus remained.

Group 4: The roentgenograms and the histological sections demonstrated a stage of fracture healing similar to that of Group 1.

Group 5: The roentgenograms demonstrated a fracture callus somewhat

smaller than that in Group 2; it was irregularly ossified. Bone union appeared sound in four of the six animals (Fig. 5-D).

On histological examination, new-bone formation was abundant. The bone trabeculae were large and well ossified. The enchondral ossification was proceeding in as orderly a fashion as that in the control rats. Some fibrocartilage was present between the bone ends, although peripheral bone union was complete.

At Three Weeks

Group 1: The roentgenograms demonstrated a well ossified fracture callus with bone union in two of three remaining animals (Fig. 6-A).

On histological examination, bone union at the fracture site appeared com-

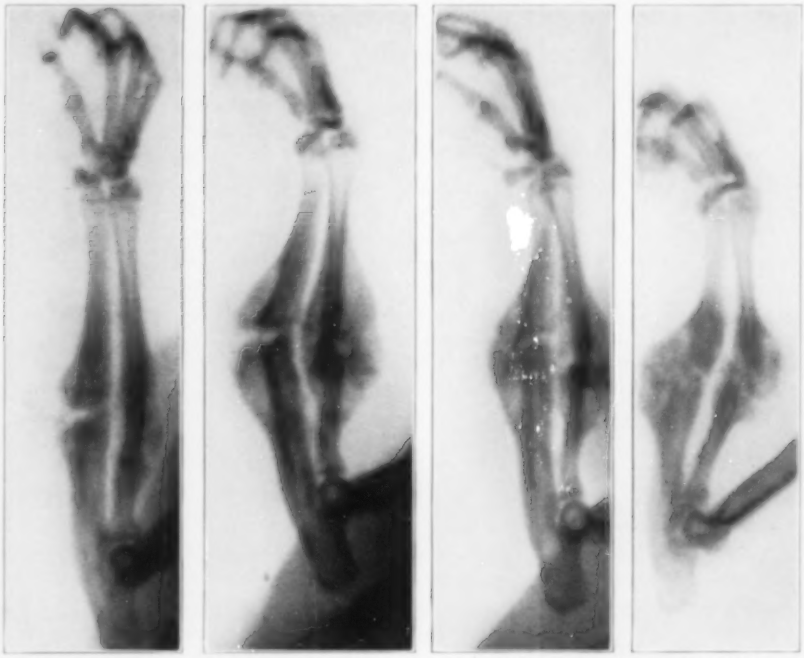

FIG. 5-A FIG. 5-B FIG. 5-C FIG. 5-D

Figs. 5-A through 5-D: Roentgenograms (×2.5) of two-week-old forearm fractures in adult rats.

Fig. 5-A: Group 1 (normal control).
Fig. 5-B: Group 2 (rats treated with aminoacetonitrile).
Fig. 5-C: Group 3 (aminoacetonitrile administered only during the first week after fracture).
Fig. 5-D: Group 5 (rats treated with aminoacetonitrile and l-triiodothyronine).

plete, although a thin zone of fibrous tissue and fibrocartilage remained in the center of the callus. The new bone trabeculae were dense and broad and surrounded by many osteoblasts and some osteoclasts (Fig. 3-A and 4-A).

Group 2: The roentgenograms revealed an extremely large and poorly calcified fracture callus; a thin superficial layer of the periosteal callus remained ossified, whereas the great mass of the callus had a very tenuous bone density. The fractures were not united (Fig. 6-B).

On histological examination, impressive changes were apparent in relation to the findings of the previous week in this group. The bone trabeculae were well ossified but sparse and separated by wide, poorly cellular vascular marrow spaces. The osteoblasts lining these bone trabeculae were much less numerous than those in rats of the previous week. These changes were present in both intra-

membranous and enchondral bone. Large areas of very cellular fibrous-connective tissue extended across the fracture line. Enchondral and intramembranous bone formation at the osteogenic front appeared to be proceeding at a very slow pace (Figs. 3-B and 4-B).

Group 3: A well ossified fracture callus larger than that in the control animals was visible in the roentgenograms; solid bone union was evident in all the animals (Fig. 6-C).

The histological sections demonstrated complete bone union with broad and well ossified bone trabeculae. A few small areas of remaining fibrous tissue and fibrocartilage were surrounded by a rapidly advancing osteogenic front.

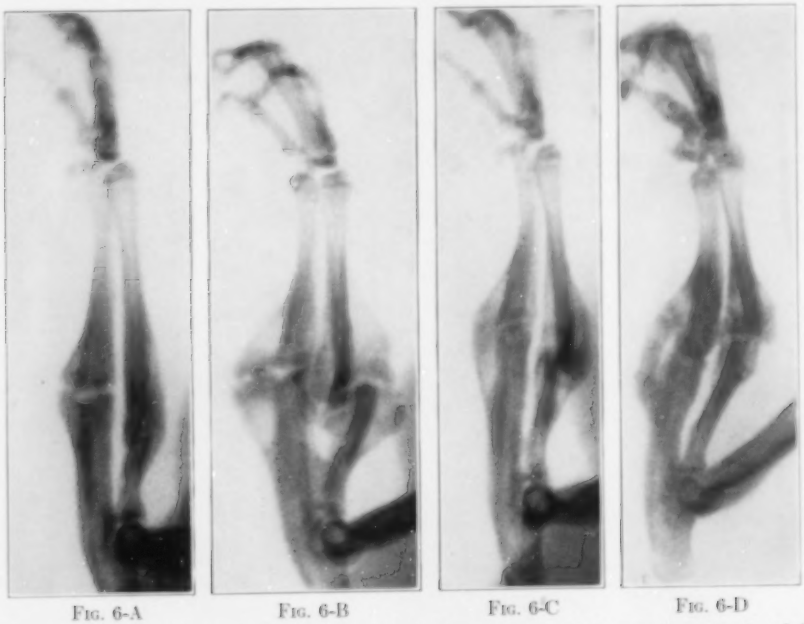

FIG. 6-A FIG. 6-B FIG. 6-C FIG. 6-D

Figs. 6-A through 6-D: Roentgenograms (×2.5) of three-week-old forearm fractures in adult rats.
Fig. 6-A: Group 1 (normal control).
Fig. 6-B: Group 2 (rats treated with aminoacetonitrile).
Fig. 6-C: Group 3 (aminoacetonitrile administered only during the first week after fracture).
Fig. 6-D: Group 5 (rats treated with aminoacetonitrile and l-triiodothyronine).

Group 4: No differences could be observed between this group and Group 1.

Group 5: In the roentgenograms the fracture callus did not appear as large as the callus in the rats of Group 2; it was much better ossified. Solid bone union was present in two of three animals (Fig. 6-D).

The regressive changes observed in the histological sections of the callus of rats of Group 2 were not apparent in this group. The bone trabeculae were broad and abundant, forming a large callus. However, a wide band of fibrous tissue and fibrocartilage remained to be ossified (Fig. 3-C).

DISCUSSION

Aminoacetonitrile administered to adult rats with experimental fractures induces the formation of a voluminous fibrocartilaginous callus [8]. Connective-tissue cells and immature cartilage cells are extremely abundant in the callus. The ground substance and the collagen fibers appear defective; the nature of this defect is not understood. Recently Castellani and Castellani have found a

decrease of the hexosamine content in the epiphyseal plates of animals treated with aminoacetonitrile. Possibly there is also defective mucopolysaccharide formation in the fracture callus of aminoacetonitrile-treated rats; the enormous cellular proliferation may be a response to the defective ground substance and may represent an effort to supply with quantity what is lacking in quality. A direct cellular stimulation by aminoacetonitrile is unlikely.

During the second week after fracture in rats receiving aminonitriles, giant bone callus develops. The new bone trabeculae are not as orderly or as uniformly ossified as those in the control animals. This result may be related to the disarrangement and to the extensiveness of the fibrocartilaginous callus. Great numbers of cartilage cells are left included in the broad new bone trabeculae. The aminonitriles do not appear to interfere at first with the intramembranous and enchondral ossification. Bone union of the fracture appears imminent at this time.

Unexpected changes occur in aminoacetonitrile-treated animals during the third week of fracture. Osteogenesis appears to cease, and even the bone trabeculae seen during the second week are reduced in number. The callus becomes very osteoporotic in appearance with few cells and many blood spaces between scanty bone trabeculae. A band of fibrous tissue crosses the callus at the fracture site, and bone union does not occur. The great cellular proliferation provoked by aminoacetonitrile ceases when the callus matures; and the large callus, with its defective ground substance, undergoes striking recessive changes.

When aminoacetonitrile is administered only during the first week after fracture a fibrocartilaginous callus larger than that in the control animals develops; but this ossifies well, and in three weeks bone union is solid. If aminoacetonitrile is administered for only four days following fracture (experiments not reported in this paper), callus slightly larger than that in the control animals develops and bone union is accelerated.

In rats treated with l-triiodothyronine alone, fracture callus develops which is apparently similar to that of the controls. When l-triiodothyronine is administered simultaneously with aminoacetonitrile, fracture callus is found which is smaller and better ossified than that in animals treated with aminoacetonitrile alone. L-triiodothyronine appears to reduce the great cellular proliferation induced by aminoacetonitrile during the first week of fracture and to stimulate cellular maturation. Enchondral ossification is better organized in the animals treated with l-triiodothyronine. The regressive changes observed during the third week of fracture in aminoacetonitrile-treated rats are restrained by l-triiodothyronine. However, in all rats treated with aminoacetonitrile and l-triiodothyronine, the fracture callus was much larger and less well formed than that in the control animals. With the doses used in our experiments l-triiodothyronine did not suppress completely the effect of aminoacetonitrile.

SUMMARY

Aminoacetonitrile administered to adult rats with experimental fractures induced the formation of a voluminous fibrocartilaginous callus which ossified well during the second week of fracture. This callus became very osteoporotic during the third week, and bone union usually did not occur.

When aminoacetonitrile was administered only during the first week after fracture, callus slightly larger than that in the control animals developed with speedier bone union.

In rats treated with l-triiodothyronine alone, fracture callus, apparently similar to that of the controls, developed.

When l-triiodothyronine was administered simultaneously with aminoacetonitrile, fracture callus, smaller and better ossified than that in animals treated with amioacetonitrile alone, formed.

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The Effect of Pressor and Depressor Drugs on Intramedullary Bone-Marrow Pressure*†

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At the present time, there is little knowledge of the physiological factors which control intramedullary bone-marrow pressure. Recently, the normal variations in pressure in the intramedullary canal of the dog's tibia and femur were studied [2]. The normal differences between diaphyseal pressure and epiphyseal pressure in the same bone were established. Therefore, a study was undertaken to determine the physiological factors which control intramedullary bone-marrow pressure. The effect of various pressor and depressor drugs on intramedullary bone-marrow pressure was investigated; the observations are the basis of this report. The only previous study of a similar nature, that we are aware of, was made by Bloomenthal. Using a mercury manometer, he observed the gross effect of various drugs on intramedullary bone-marrow pressure.

METHODS

As in previous studies, the pressures were recorded from the tibiae of adult dogs by inserting a Vitallium tap into the bone. The Sanborn electromanometer, with water as a connecting medium, was used to record the marrow pressures. The Offner multirecorder was employed to transcribe the records. The handling of the dogs, calibration of the manometers, anaesthesia, and heparinization were carried out in exactly the same manner as was used in studying the normal pressure variations [2].

In this study all observations were made from the tibia. In most experiments recordings of marrow pressure were made simultaneously from the right and left tibial diaphyses. Both femoral arteries were exposed for a distance of one centimeter at the level of the femoral triangle. The left femoral artery was, in all experiments, used for recording the systemic-arterial pressure. The arterial pressure was obtained by inserting a 20-gauge needle into the vessel, and the recording was obtained from a third Sanborn manometer. The arterial pressure was recorded simultaneously with the diaphyseal pressure of both the right and the left tibia, or the epiphysis and diaphysis of the same bone. The right femoral artery was, in all experiments, used only for the injection of intra-arterial drugs.

Following the surgical exposures, each animal was heparinized (ten milligrams per twenty pounds). After heparinization, the bones were drilled, the taps were inserted, and the femoral artery was cannulated. Following a short period of normal recording, the effects of adrenalin, nor-epinephrine, pituitrin, amphetamine, histamine, acetylcholine, and atropine were observed and recorded. Each drug was given intravenously in the right foreleg; and later, after the normal had been re-established, an intra-arterial injection was made into the right femoral artery. In each experiment, two or three of the drugs were tested. In all cases, the volume of the intra-arterial injection was one cubic centimeter, or less. The injection was made through a 25-gauge needle. At the termination of each

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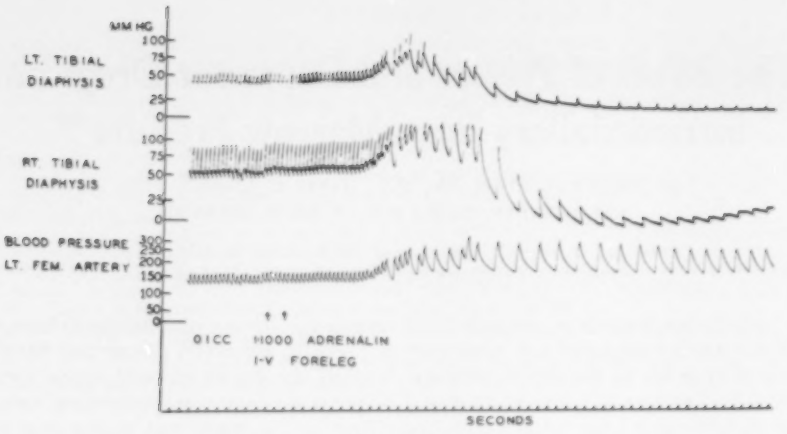

CHART I-A

The effect of intravenous adrenalin on diaphyseal pressure in the right and left tibia.

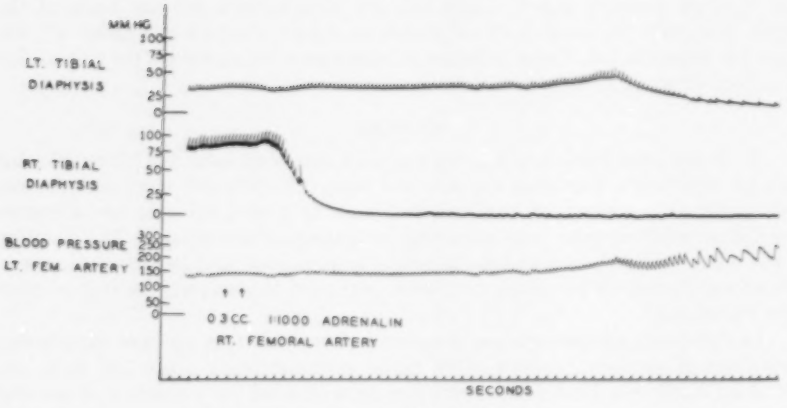

CHART I-B

The effect of adrenalin when injected into the right femoral artery; the local action is well shown in this record.

experiment the dog was sacrificed, and the bones that had been studied were removed. A roentgenogram of the bone was made so that the exact site of pressure measurement and the state of the epiphyseal plate could be known. All of the observations were made in fourteen adult dogs with closed epiphyses.

OBSERVATIONS

Adrenalin

In ten experiments, 0.1 cubic centimeter of 1:1000 adrenalin was injected into the vein of the foreleg, and the intramedullary pressure was altered in a constant and reproducible pattern. Pressure changes in the epiphysis and diaphysis corresponded in the pattern of reaction and varied only in their magnitude. A marked fall in the intramedullary pressure was always observed, and this was associated with a marked decrease in the pulse pressure within the medullary canal. The fall in pressure began within four to six seconds after a short period of initial rise in pressure.

The decreased pressure within the bone was maintained for several minutes at about half of the pre-injection level. In all experiments the lowered intra-

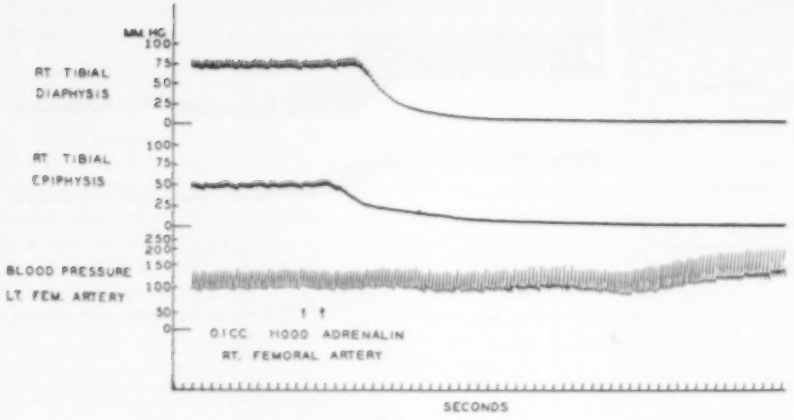

CHART I-C

The effect of adrenalin on the epiphysis and diaphysis; injection was made into the right femoral artery.

medullary pressure was associated with a sustained rise in the arterial-blood pressure to a level of 210 systolic, 150 diastolic to 290 systolic, 150 diastolic. (The mean femoral arterial pressure in the fourteen experimental animals prior to the injection of drugs was 138 systolic, 98 diastolic millimeters of mercury.) This rise in systemic-blood pressure started simultaneously with the short initial rise in marrow pressure (Chart I-A).

In five experiments, an intra-arterial injection of adrenalin 1:1000 (0.1 to 0.3 cubic centimeter) was made into the right femoral artery while the pressure in both the right and left tibial diaphysis was recorded simultaneously. In each such experiment, the bone-marrow pressure immediately fell on the injected side. This fall was not associated with an initial rise, and in all cases the fall approached zero with obliteration of a recordable pulse pressure. This change was sustained for from twenty-five to thirty minutes (Chart I-B). In twenty to thirty-six seconds following the intra-arterial injection, the tibial pressure on the side in which no injection was made was altered in exactly the same pattern as observed when adrenalin was injected intravenously. The arterial-blood pressure demonstrated a sustained rise as the marrow pressure was altered on the side in which no injection was made. Pressure in the epiphysis and diaphysis responded in the same pattern and varied only in the degree of change (Chart I-C).

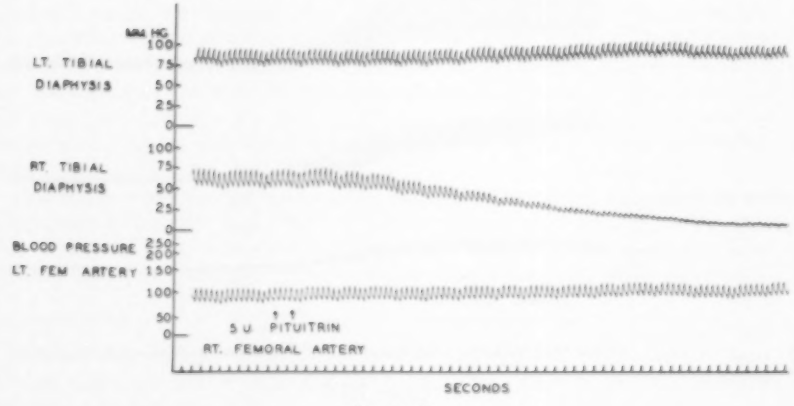

CHART II

The effect of pituitrin given into the right femoral artery.

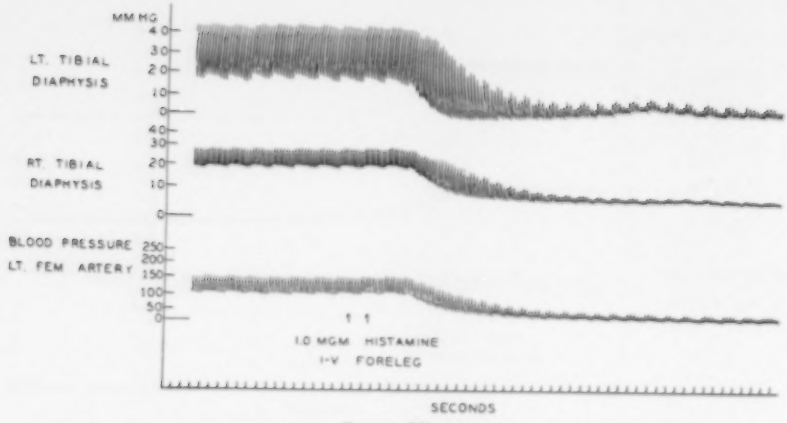

CHART III-A

The effect of intravenous histamine on diaphyseal pressure.

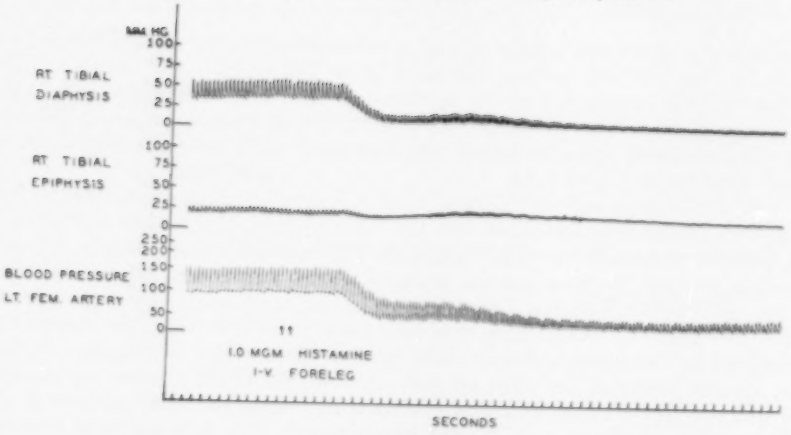

CHART III-B

The effect of intravenous histamine on epiphyseal and diaphyseal pressure.

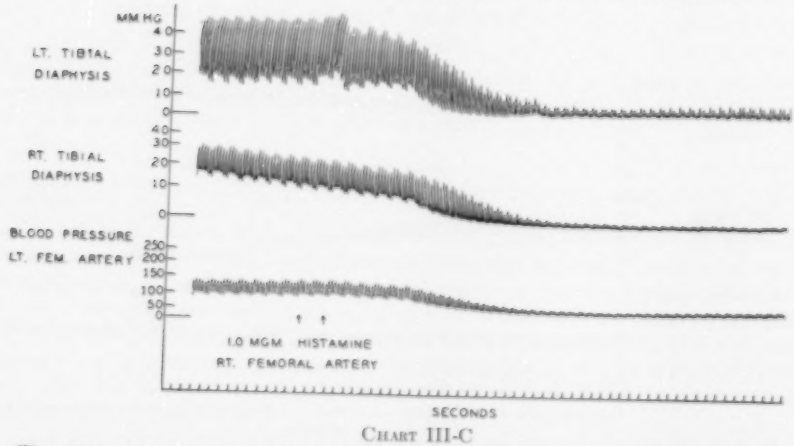

CHART III-C

The effect of histamine on diaphyseal pressure when injected in the right femoral artery.

After the maximum fall in marrow pressure, the drill hole in the diaphysis was opened. In each case, it was noted that there was no bleeding from the drill site.

Nor-epinephrine

Eight observations of the effect of nor-epinephrine on intramedullary bone-marrow pressure were made. In four experiments 0.2 to 1.5 cubic centimeters of nor-epinephrine were injected intravenously into the foreleg. The same pattern of alteration of marrow pressure and systemic-blood pressure was observed as when adrenalin was given. The only difference we have observed between adrenalin and nor-epinephrine is that there is less cardiac irregularity with nor-epinephrine. On four occasions a similar dose of nor-epinephrine was injected into the right femoral artery. There was an immediate fall in diaphyseal-marrow pressure and pulse pressure on the right side, while several seconds later the typical changes of intravenous administration were seen in the left tibial diaphysis when larger amounts were given.

Pituitrin

When, in three experiments, five units of pituitrin was injected intravenously into the foreleg, there was a short initial rise in marrow pressure followed by a marked and prolonged fall in intramedullary pressure. This change was associated with a decrease in pulse pressure. In three experiments in which the systemic-blood pressure was recorded simultaneously, there was a mild increase in systemic-blood pressure. In three observations the pattern of change in marrow pressure, when pituitrin was given by intra-arterial injection, was similar to the effect of adrenalin. The only difference we have observed is in the magnitude of the alteration—it was less pronounced with pituitrin particularly with intra-arterial administration (Chart II).

Histamine

When 1.0 milligram of histamine was injected intravenously into the foreleg, a constant and reproducible alteration of marrow pressure was observed in seven experiments. The changes in diaphyseal pressure, epiphyseal pressure, and systemic-blood pressure occurred simultaneously and began three to six seconds after the start of the injection. There was a short period of increased pulse pressure which was observed as the marrow pressure and systemic-blood pressure began to fall (Chart III-A). The maximum fall in pressure occurred in from twenty-three to twenty-nine seconds, and was maintained for one to five minutes.

The fall in pressure was less in the epiphysis. Diaphyseal pressure tended to approach epiphyseal pressure, but remained slightly higher (Chart III-B). As the maximum fall in pressure was reached, there was a decrease in pulse pressure, but, in all experiments, a pulse pressure was easily recorded in both the epiphysis and diaphysis at the time of maximum decrease in pressure. The mean fall in the diaphyseal pressure was 29.9 $\pm$ 15.6 millimeters of mercury. The mean fall in epiphyseal pressure was 7.7 $\pm$ 6.5 millimeters of mercury. These differences are significant at the 5 per cent level.

Histamine was injected on four occasions into the right femoral artery. The alterations in marrow and systemic-blood pressure were similar to the changes seen when the drug was given intravenously. The only difference was that the onset of the effect was slightly delayed after intra-arterial injection (Chart III-C).

Amphetamine

When ten milligrams of amphetamine was injected intravenously into the foreleg a gradual and sustained rise of diaphyseal-marrow pressure occurred in five tibiae studied.

Thirty seconds after injection, the mean increase in marrow pressure was

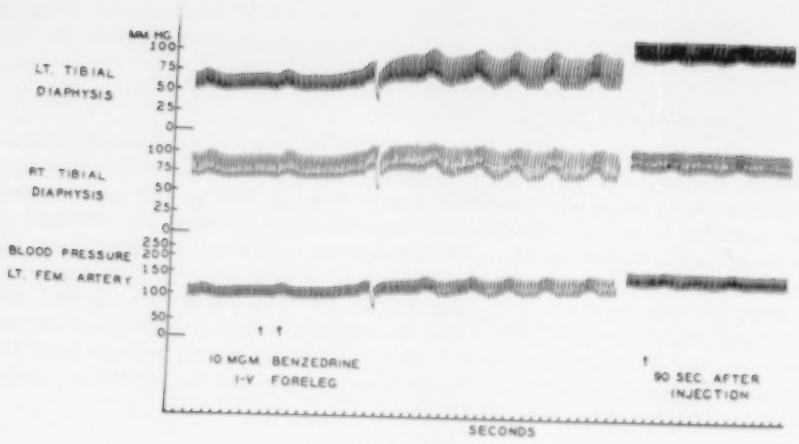

CHART IV

The effect of intravenous benzedrine on diaphyseal pressure.

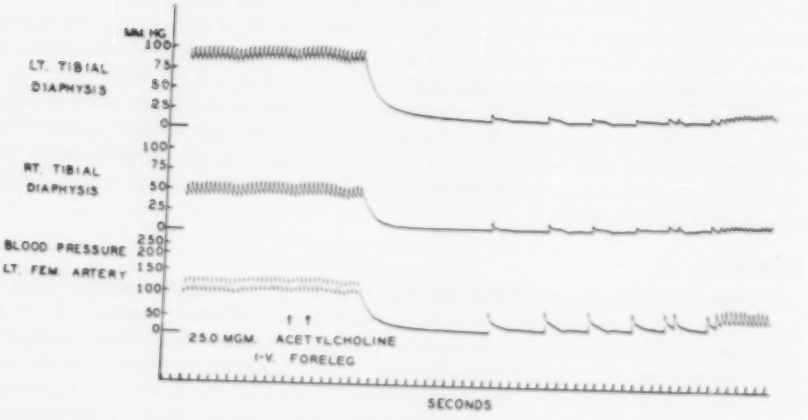

CHART V

The effect of intravenous acetylcholine on diaphyseal pressure.

thirty-two millimeters of mercury. In sixty seconds, it was thirty-three millimeters of mercury. Thirty seconds after injection, the mean increase in arterial systolic pressure was fifty-five millimeters of mercury; in sixty seconds, it was sixty-three millimeters of mercury. The changes in marrow and systemic pressures occurred simultaneously (Chart IV).

Injection of amphetamine into the right femoral artery in these dogs produced a simultaneous rise of pressure in both tibiae and in arterial systolic pressure. This pattern of change was comparable to that seen when the injection was done intravenously.

Acetylcholine

In three experiments 12.5 milligrams of acetylcholine was injected intravenously into the foreleg. This produced a sudden fall in diaphyseal-marrow pressure and arterial-blood pressure which occurred in seven to nine seconds. The fall approached zero and was associated with vagal heart block. During the ensuing one to two minutes, there was a gradual return of the pressures to normal as the heart regained its normal rhythm (Chart V). On two occasions, the injection was made into the femoral artery and the response was essentially the same.

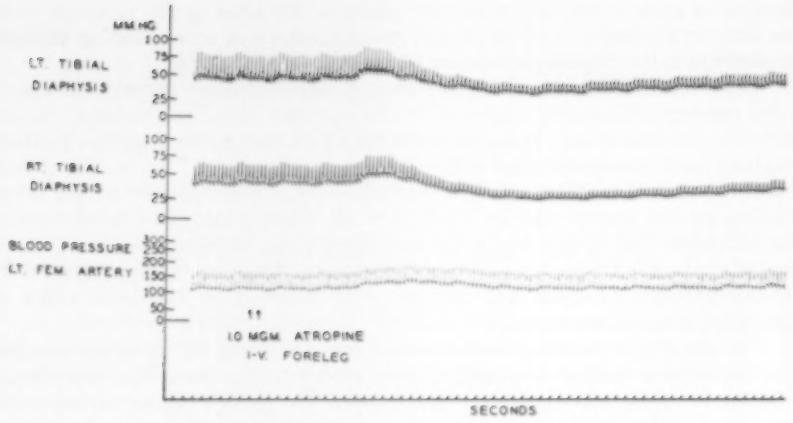

CHART VI-A

The effect of intravenous atropine on diaphyseal pressure.

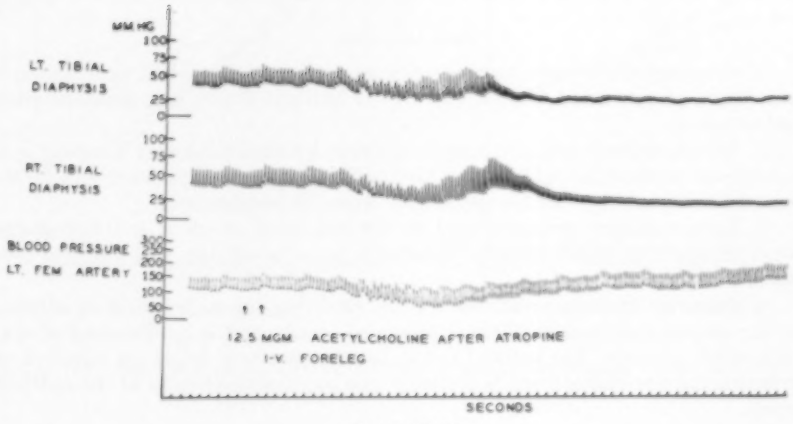

CHART VI-B

The effect of intravenous acetylcholine after the dog has been atropinized.

Atropine

Upon the intravenous administration of 1.0 milligram of atropine in three dogs, a slight rise in systemic pressure was observed. This was accompanied by a slight rise in diaphyseal-marrow pressure which lasted for three to four seconds. This rise was followed by a fall in marrow pressure with a decrease in pulse pressure—the pattern of change being similar to the effect of adrenalin (Chart VI-A).

When acetylcholine (12.5 milligrams) was injected intravenously into the previously atropinized dog, the vagal block of the heart was prevented. Under these circumstances, there was a slight fall in marrow and systemic pressure which occurred simultaneously. This was promptly followed by a typical adrenalin-like response which was probably due to the nicotinic-acid-like effect of acetylcholine (Chart VI-B).

DISCUSSION

From the data presented, it would appear that the level and variation of bone-marrow pressure in the dog is dependent on at least two physiological factors

The first of these is the systemic-blood pressure. By altering the systemic pressure with amphetamine and histamine, simultaneous and corresponding changes are observed in the diaphyseal-marrow pressure.

The second factor influencing the level of intramedullary pressure is related to the patency of the small nutrient vessels carrying blood to the bone, particularly the nutrient artery. It appears that adrenalin and nor-epinephrine produce a marked local vasoconstriction of the vessels supplying bone. This is independent of their effect on the systemic-blood pressure. This is substantiated by the effect of adrenalin and nor-epinephrine when they are injected into the femoral artery. The immediate fall of pressure in the ipsilateral tibia represents the local effect. The delayed pressure changes of the contralateral tibia are a manifestation of systemic-pressure elevation and are promptly followed by the local effect—a marked fall in marrow pressure.

The absence of bleeding from the drill hole following the injection of adrenalin indicates a marked decrease in blood supply to the bone. This is believed to be due to vasoconstriction of nutrient vessels. The sudden fall in marrow pressure following the intra-arterial injection of adrenalin is similar to the sudden fall in pressure which occurs when the main nutrient artery to the diaphysis is sectioned. We do not believe, as Bloomenthal stated, the fall in pressure in the marrow is due to dilation of arterioles and capillaries within the marrow cavity.

CONCLUSIONS

1. Intramedullary bone-marrow pressure levels are dependent upon the systemic-blood pressure and the patency of the nutrient artery and possibly other smaller vessels.

2. Intramedullary pressure may be lowered by simultaneously lowering systemic-blood pressure by injection of histamine. The marrow pressure can be increased simultaneously with the systemic pressure by amphetamine.

3. Intramedullary pressure may be lowered while there is a simultaneous rise in the systemic-blood pressure. Adrenalin, nor-epinephrine, and pituitrin produce the response.

4. From the evidence presented, it is believed that the major effect of adrenalin, nor-epinephrine, and pituitrin is produced locally and is independent of systemic-blood pressure. The marked fall in marrow pressure following injection of adrenalin and nor-epinephrine is probably due to vasoconstriction of the nutrient vessels.

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Minerals, Collagen, and Hexosamine in Rat Femora*

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In a previous communication, the results of a study on the growth of collagen and hexosamine of the femora of young rats were reported [2]. With growth, collagen is laid down at a greater rate than is hexosamine. The latter substance

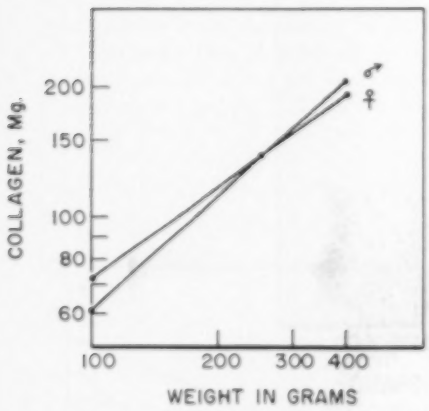

CHART I

Body weight and collagen content of both femora.

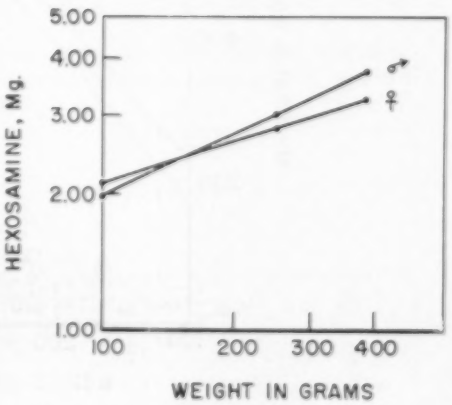

CHART II

Body weight and hexosamine content of both femora.

TABLE I

CORRELATION OF COLLAGEN (*C*), HEXOSAMINE (*H*), AND MINERALS (*M*) CONTENT OF BOTH RAT FEMORA WITH BODY WEIGHT (*W*).

	Males: 74		
1. Log C	= .02310 + .88252 Log W	r = .986	Sy = .0465
2. Log H	= − .62173 + .46002 Log W	r = .956	Sy = .0436
3. Log M	= − 2.98226 + 1.12209 Log W	r = .989	Sy = .0529
4. Log M	= − 2.99182 + 1.26142 Log C	r = .995	Sy = .0367
5. Log M	= − 1.39252 + 2.2539 Log H	r = .956	Sy = .0103
6. Log H/C†	= − 0.64483 − .42250 Log W		
	Females: 39		
1. Log C	= .41734 + .71948 Log W	r = .965	Sy = .0346
2. Log H	= − .21983 + .27969 Log W	r = .819	Sy = .0349
3. Log M	= − 2.75209 + 1.04926 Log W	r = .964	Sy = .0512
4. Log M	= − 3.29057 + 1.42366 Log C	r = .974	Sy = .0429
5. Log M	= − 1.50693 + 2.71100 Log H	r = .851	Sy = .1013
6. Log H/C†	= − 0.63717 − 0.43979 Log W		

† Derived equation.

* Supported by a grant from the United States Public Health Service.

is a constituent of the mucopolysaccharides of the ground substance. The observation that the ratio of hexosamine to collagen diminishes with growth of the femur is part of a general phenomenon of connective tissue, and this has been made the basis for a theory of aging [3]. This series has now been extended to include rats up to one year of age. The mineral content has been studied as well.

METHODS

The analytical procedures for hexosamine and collagen were carried out as previously described [2]. Minerals were determined by the difference in weight be-

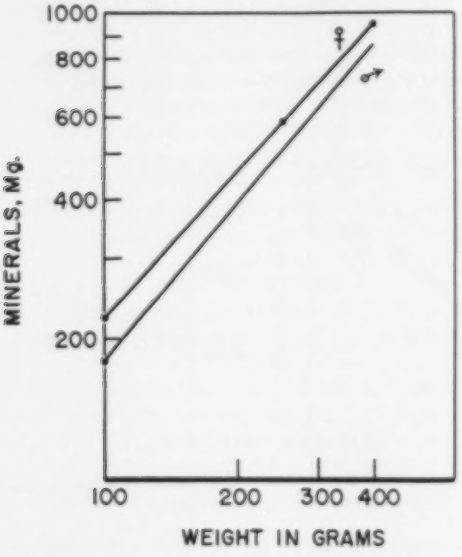

CHART III

Body weight and mineral content of both femora.

tween the dried defatted bone and the acetone dried residue after treatment with cold trichloracetic acid. Statistical treatment was also carried out as previously described*.

The age selection of animals did not follow a definite pattern. Thirty-one male rats ranged in age from newly weaned to under three months, twenty-eight from three to six months, and fifteen from nine to twelve months. Sixteen female rats ranged in age from newly weaned to under three months, eleven from three to six months, and twelve from nine to twelve months.

RESULTS

The findings were documented in the form of the regression of the dependent variable (collagen, hexosamine, and mineral) on weight. Log-Log correlations of extremely high statistical significance were obtained (Table I).

In order to more clearly present the data, the equations are plotted in Charts I, II, and III. Several interrelationships of collagen, hexosamine, and mineral were also derived (Charts IV and V).

Significant sex differences were not observed for the quantity of each constituent in rats between 100 and 400 grams in weight. However, the mineral content was consistently greater in the females, suggesting that a sex difference could exist in this case.

* Calculation of regression coefficient was erroneously given as $\frac{k}{SS_x\, SS_y}$. It should read $\frac{k}{\sqrt{SS_x\, SS_y}}$.

TABLE II

COLLAGEN, HEXOSAMINE, AND MINERALS IN ESTROGEN TREATED RATS

	Mean Weight	Mean Femur Length	Collagen Observed	Collagen Calculated	Hexosamine Observed	Hexosamine Calculated	Minerals Observed	Minerals Calculated
Controls	251	6.17	138	139	2.88	3.00	518	510
Estrogen treated	163	5.53	99	94	2.56	2.45	451	310*♂ 370♀

* Values expected if the male or female equation in Table I is used.

Calculations were made at the net deposition of each constituent per gram of gain in body weight (Chart IV). This rate was greater in males for both collagen and hexosamine. This accounts for the greater values of these constituents in the larger males (Charts I and II). Of great interest is the fact that the rate of deposition of these constituents diminished with growth, hexosamine more so than collagen. On the other hand, the rate of growth of minerals remained relatively constant, increasing slightly.

The deposition of minerals per milligram of growth of collagen and hexosamine is shown in Chart V. Deposition rate increased with growth and was greater in the female than in the male.

The influence of estrogen administration was investigated. Eight newly

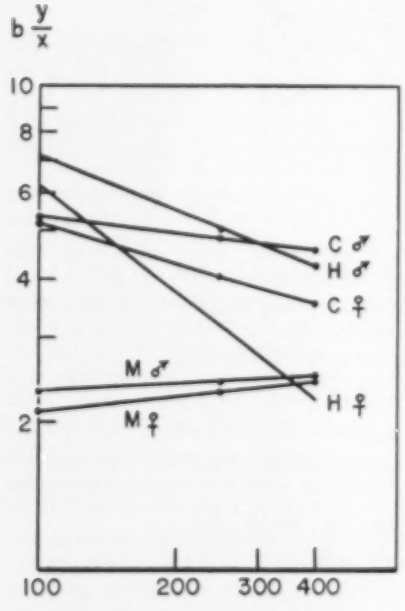

CHART IV

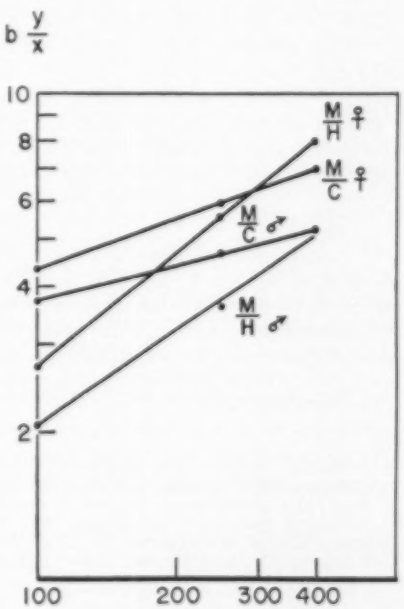

CHART V

Chart IV: Body weight and net deposition of collagen (C) and hexosamine $\times 10^2$ (H) per gram gain in body weight $\left(b\frac{y}{x}\right)$. Derived as follows: $\log y = a + b \log x$; $y = ax^b$; $\frac{dy}{dx} = abx^{b-1}$; $\frac{dy}{dx} = \frac{y}{x}b$; $bx^{b-1} = b\frac{y}{x}$.

Chart V: Body weight and net deposition of minerals per milligram of collagen $\left(\frac{M}{C}\right)$ and minerals per milligram $\times 10^2$ hexosamine $\left(\frac{M}{H}\right)$.

weaned male rats were injected subcutaneously with increasing amounts of alpha-estradiol starting with a daily dose of ten micrograms in 0.05 cubic centimeters of corn oil. The dose was increased by increments of ten micrograms weekly until each rat received fifty micrograms daily. The rate of growth was decreased so that at ninety-five days the rats weighed 150 to 177 grams which is the normal weight for females of this strain. The results are shown in Table II. The collagen, hexosamine, and mineral content of age controls was consistent with values obtained from the regressions. The collagen and hexosamine contents of the growth-retarded animals following estrogen treatment were normal for animals of the final weight attained. The mineral content, however, greatly exceeded the expected value.

DISCUSSION

The minerals of the femur showed a different growth pattern from that of collagen and hexosamine. The latter grew at a diminishing rate, while mineral deposition was maintained at nearly a constant rate. Thus the percentage composition of the femur with regard to these constituents is a function of growth.

Although significant sex differences were not observed in the quantity of collagen and hexosamine present in the rat femora, it seemed that these substances were deposited at a greater rate in males. Since estrogen administration did not significantly alter the collagen and hexosamine contents of the femur from that expected for rats of similar weights, it is possible that the apparent differences in rates of growth of these substances were related to differences in growth rate of the whole organism, rather than to their direct specific influences. These data are insufficient to draw a final conclusion, however.

It is apparent that mineralization was greatly increased following estrogen administration over that which is normally found for animals of the given weight. The hypermineralizing influence of estrogen in the rat has been reported by many authors although disputed by some [1]. It must be inferred that the mechanism of action of estrogen in producing hypermineralization is different from that which controls collagen formation.

SUMMARY

The growth of minerals, collagen, and hexosamine in the femora of rats ranging in age up to one year was studied. Significant sex differences were not observed in the quantities of these substances. The data suggested, however, that the mineral content might be greater in females than in males, and it was observed that estrogen administration increased mineral content.

NOTE: Statistical data were calculated by Dr. Frederick J. Moore.

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The Extra-osseous and Intra-osseous Blood Supply of the Talus*

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Roman soldiers made their dice from the heel bones of horses; hence the heel bone became known as the *taxillus*, meaning die. Later the word was shortened to talus. The Greeks made dice from the second cervical vertebra of sheep and called this bone *astragalos*. The two words thus came to be applied to the same bone in the tarsus because both were associated with the manufacture of dice [4]. Talus is used here in preference to astragalus because the derivation of the word *talus* shows it to be anatomically correct. Talus is also the officially accepted anatomical term.

Orthopaedic surgeons are aware of the importance of the blood supply of the talus as it relates to the outcome of fractures and of surgical procedures performed on this bone. Avascular necrosis of the body of the talus frequently follows fracture-dislocation of the neck of the talus. Marek and Schein have reported avascular necrosis of the body of the talus following triple arthrodesis.

The extra-osseous blood supply of the talus was accurately described by Wildenauer in 1950 but his report has not been presented in the English literature. The talus is supplied with blood by the three main arteries of the lower portion of the leg through a periosteal vascular network, which covers all of the cartilage-free surfaces, and by two discrete vessels: the artery of the tarsal sinus and the artery of the tarsal canal. The tarsal sinus faces anterolaterally and is bounded by the inferolateral surface of the neck of the talus above and in front, by the anterolateral surface of the body of the talus behind, and by the anterosuperior surface of the calcaneus below. The tarsal canal is formed by the talar sulcus and the calcaneal sulcus; it measures about five millimeters in diameter and perforates the tarsus from the posteromedial to the anterolateral region. The canal extends about 1.5 centimeters and opens abruptly into the funnel-shaped tarsal sinus. The artery of the tarsal sinus arises variably from the dorsalis pedis, the lateral malleolar, or the perforating branch of the peroneal artery and courses through the sinus to the tarsal canal where it anastomoses with the artery of the tarsal canal. The artery of the tarsal canal arises consistently from the posterior tibial artery about two centimeters below the ankle joint, passes forward through the ligamentum deltoideum, branches to the medial side of the talus, and disappears into the tarsal canal. Wildenauer stated that the vessels of the tarsal sinus and tarsal canal, together with the medial periosteal network, are the most important source of blood to the talus.

The vascular foramina of the talus were described by Sewell in 1904 in his studies of more than 1,000 dried specimens. Vascular foramina are found on the superior, lateral, and inferior surfaces of the neck and on the medial surface of the body. The largest and most numerous foramina are found on the part of the inferior surface of the neck which constitutes the roof of the tarsal canal.

Attempts to demonstrate the intra-osseous blood supply of the talus by injection techniques have been unsuccessful [2,5]. McKeever, in 1943, suggested that the main blood supply to the body of the talus entered through the superior surface of the neck.

*Read at the Combined Meeting of the Orthopaedic Research Society and The American Academy of Orthopaedic Surgeons, New York, N. Y., February 1, 1958.

†The Mayo Foundation, Rochester, Minnesota, is a part of the Graduate School of the University of Minnesota.

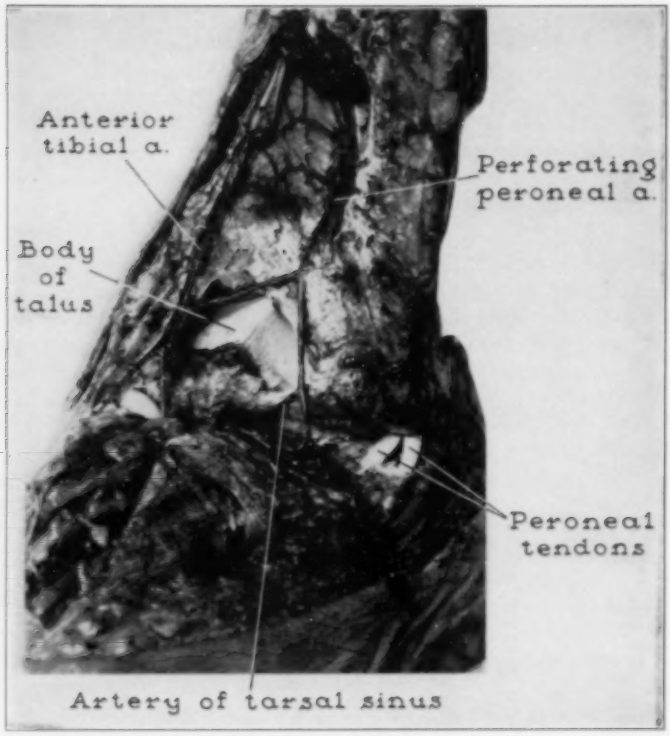

FIG. 1

Dissection of a left foot showing the artery of the tarsal sinus arising from the perforating peroneal artery. The vessels were injected with an India-ink and gelatin suspension.

MATERIALS AND METHODS

Fourteen legs which were amputated for non-vascular diseases were utilized for this study. Usually amputation was performed because of malignant disease in the thigh or pelvis. Immediately following operation the extremity was disarticulated at the knee, and the popliteal vessels were cannulated. The vascular tree was then irrigated with 1,000 cubic centimeters of a solution of one gram of sodium nitrite in physiological saline. A micropaque suspension was injected into two legs and India ink in suspension was injected into twelve legs. The tali injected with the micropaque suspension were decalcified, sectioned, and studied by microradiography, but this technique failed to demonstrate the vascular pattern adequately. The vascular pattern outlined by barium, however, was visible to the naked eye when these specimens were cleared by the Spalteholz technique[6]. We then decided to use the Spalteholz technique exclusively with India ink which gives a better visual contrast in the vessels. The India-ink suspension was made up of three parts India ink to one part distilled water with five grams of gelatin and 0.1 gram of sodium nitrite per 100 cubic centimeters of solution. Three to four hundred cubic centimeters of injection material was used and the injection was usually completed within two to three hours after the amputation. The leg was stored in the refrigerator and dissected two or three days later. The talus was then disarticulated, fixed in formalin, decalcified in 15 per cent formic acid, sliced at intervals of two to three millimeters in various planes, and cleared by the Spalteholz technique. The entire process required about five to six weeks.

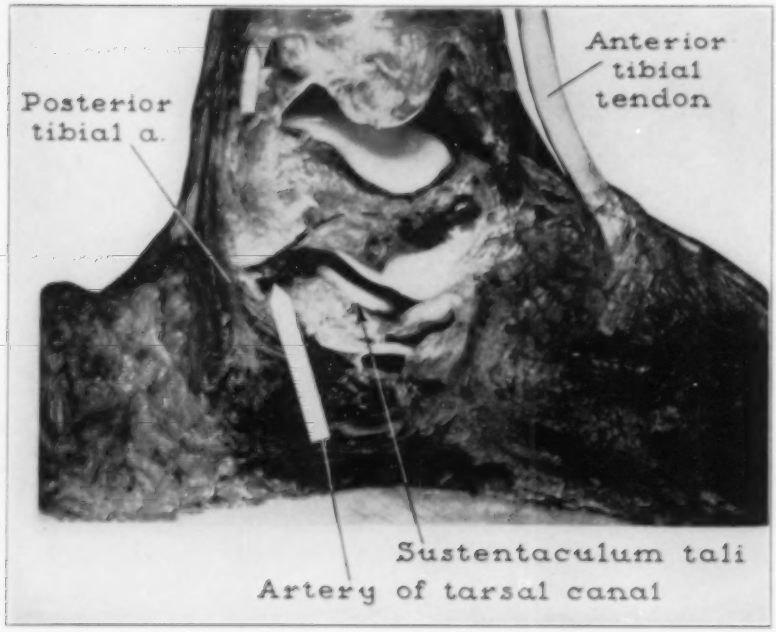

FIG. 2

Dissection of a left foot showing the artery of the tarsal canal arising from the posterior tibial artery with a branch to the medial side of the body of the talus. The vessels were injected with an India-ink and gelatin suspension.

FINDINGS

Gross Dissection

An artery of the tarsal sinus was found in five of the fourteen specimens; in three specimens it arose from the perforating branch of the peroneal artery and in two specimens from the lateral malleolar artery (Fig. 1). This distinction in origin is not important, because of the close anastomotic connections between the lateral malleolar and perforating branch of the peroneal arteries. The arteries of the tarsal sinus were one to two millimeters in diameter. Often much smaller vessels arising from the lateral malleolar or lateral tarsal arteries were found to enter the sinus.

An artery of the tarsal canal was found in thirteen of the fourteen specimens (Fig. 2). This artery was consistently found arising from the posterior tibial artery about two to three centimeters below the level of the ankle joint. In six specimens the artery branched to the medial side of the body of the talus and disappeared into the tarsal canal. In six specimens the artery was traced to the medial side of the talus but no branch into the canal was identified. It is noteworthy that these specimens were among the first dissected and it is possible that a branch to the canal was present but not identified. In one specimen the artery went directly into the canal without a branching to the medial side of the talus.

The Intra-osseous Vascular Pattern

The bones were so densely filled with injection material that it was necessary to slice them into sections two to three millimeters thick in order to identify the vascular pattern. Each talus was sectioned in one of three planes—coronal, sagittal, or oblique—after decalcification and prior to the clearing process (Figs. 3, 4, 5-A, and 5-B). In all specimens the intra-osseous vascular pattern was clearly

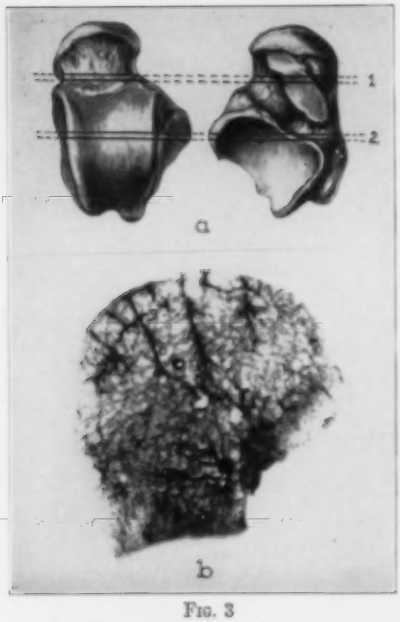

FIG. 3

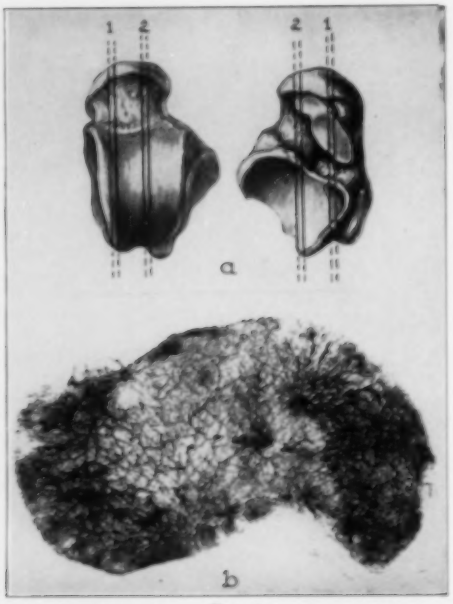

FIG. 4

Fig. 3, *a*: Superior and inferior view of a right talus to show the site of origin of the coronal sections shown in Fig. 3, *b* and Fig. 7, *a*.

Fig. 3, *b*: Coronal section through the neck of the talus at the site indicated by section 1 in Fig. 3, *a* after use of Spalteholz preparation. The vessels were injected with an India-ink and gelatin suspension. Note vessels entering the bone from the superior and the inferolateral surfaces.

Fig. 4, *a*: Superior and inferior views of a right talus showing the site of origin of the sagittal sections shown in Fig. 4, *b* and Fig. 6, *a*.

Fig. 4, *b*: Sagittal section through the talus at the site indicated by section 1 in Fig. 4, *a* after use of Spalteholz preparation. The vessels were injected with an India-ink and gelatin suspension. Note the vessels entering the head of the talus from the superior surface and the vessels cut in cross-section entering the medial side of the body.

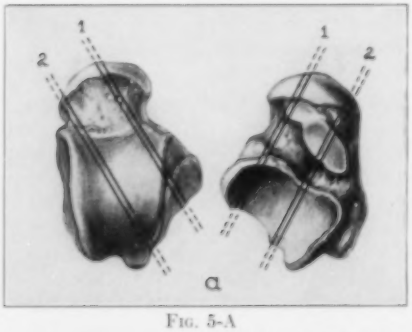

FIG. 5-A

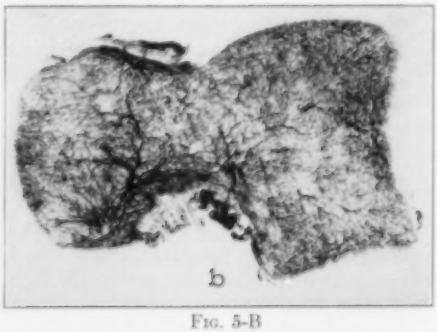

FIG. 5-B

Fig. 5-A: Superior and inferior view of right talus to show the site of origin of the oblique sections shown in Figs. 5-B and 8, *a*.

Fig. 5-B: An oblique section of the talus at the site indicated by section 1 in Fig. 5-A after use of Spalteholz preparation. The vessels were injected with an India-ink and gelatin suspension. Note the vessels entering the head from the superior and inferolateral surfaces. There is a relative absence of vessels entering the body from the anterolateral surface.

visualized. We are unable to state whether the vessels seen are arteries or veins, because the injection material filled both sides of the vascular tree. The vessels will be described according to their surface of origin and their destination to either the head or body of the talus.

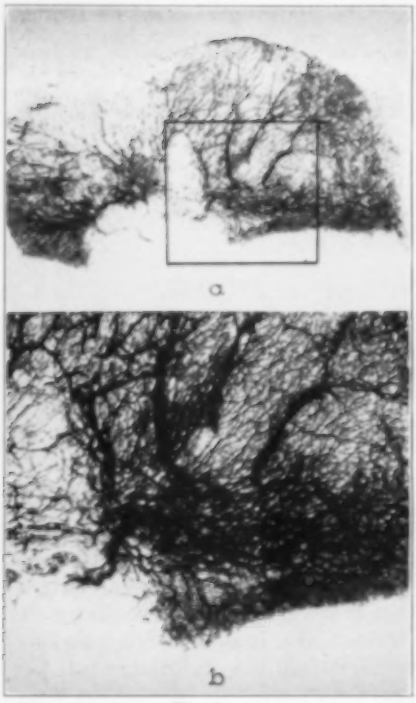

FIG. 6

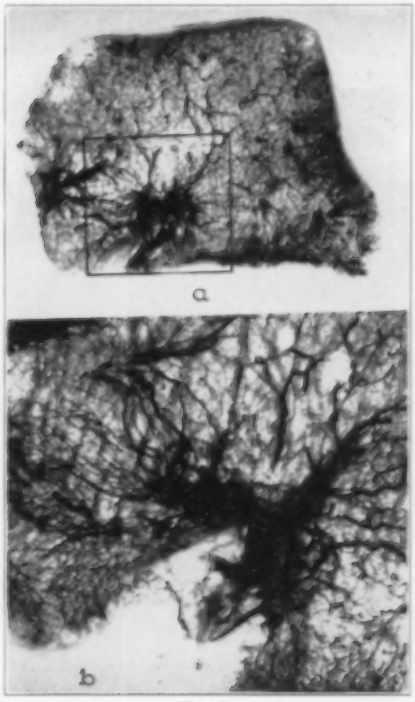

FIG. 7

Fig. 6, *a*: Sagittal section through the talus at the site indicated by section 2 in Fig. 4, *a* after use of Spalteholz preparation. This section is from the same talus as the section shown in Fig. 4, *b*. Note the large vessels entering the talus inferiorly from the tarsal sinus. There is a small vessel entering the body through the posterior tubercle.

Fig. 6, *b*: A higher power photograph of the section outlined in Fig. 6, *a*.

Fig. 7, *a*: Coronal section through the body of the talus at the site indicated by section 2 in Fig. 3, *a* after use of Spalteholz preparation. This section is from the same talus that the section shown in Fig. 3, *b* is taken from. Note the large vessels entering the bone inferiorly through the roof of the tarsal canal and medially below the articular facet for the malleolus tibiae.

Fig. 7, *b*: A higher power photograph of the opposite side of the specimen of the section shown in Fig. 7, *a*.

The head of the talus is supplied by vessels which descend into it from the superior surface of the neck (Figs. 3, *b*, 4, *b*, and 5-B), and also by vessels which enter from the inferolateral surface of the neck which faces the tarsal sinus (Figs. 3, *b*, 5-B, and 6, *a*). Vessels from these two surfaces of origin contribute about equally to the blood supply of the head.

The body of the talus is supplied by vessels which enter from five surfaces: the superior surface of the neck, the anterolateral surface of the body which faces the tarsal sinus, the inferior surface of the neck which is the roof of the tarsal canal, the medial surface of the body below the articular facet for the malleolus tibiae, and the posterior tubercle. The largest vessels in all specimens entered the body antero-inferiorly through the neck of the talus (Figs. 6, 7, and 8). These vessels arch upward and pass posteriorly and laterally into the body. The next largest vessels enter from the medial surface and ramify in the medial side of the body (Figs. 4, *b* and 7, *a*). Vessels from the superior surface of the neck (Fig. 8, *a*), the anterolateral surface of the body (Fig. 5-B) and the posterior tubercle (Fig. 6, *a*) were considerably smaller and contributed about equally to the blood supply of the body.

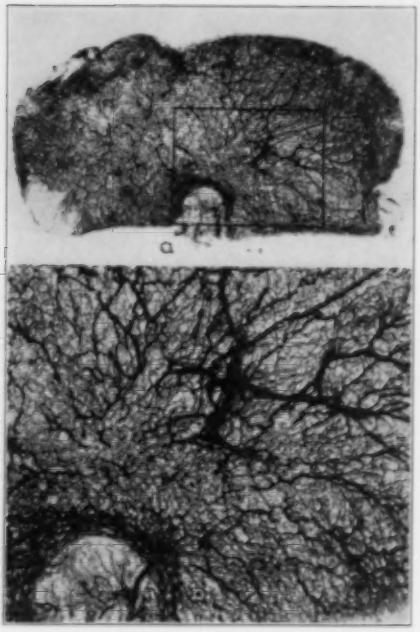

FIG. 8

Fig. 8, *a*: Oblique section of the talus at the site indicated by section 2 in Fig. 5-A after use of Spalteholz preparation. This section is from the same talus as the section shown in Fig. 5-B. Note the large vessel entering the section a short distance above the roof of the tarsal canal and passing posteriorly and laterally into the body of the talus. There is a smaller vessel entering the body from the superior surface of the neck.

Fig. 8, *b*: Region outlined in Fig. 8, *a*.

COMMENT

The major part of the blood supply to the body of the talus enters antero-inferiorly through the neck of the talus. Blood is brought to this part of the bone by a "sling" anastomosis of the artery of the tarsal sinus approaching from the anterolateral aspect and the artery of the tarsal canal approaching from the posteromedial aspect. There is also a rich blood supply entering from the medial surface below the articular facet for the malleolus tibiae. It is apparent, from this study, that the importance of the blood supply to the body entering through the superior surface of the neck has been overestimated. If one were to make dice from human tali by amputating the anterior portions flush with the anterior margin of the superior articular facet, the vascular foramina of the tarsal canal and the medial surface would be left undisturbed.

SUMMARY

The talus is supplied with blood by the three main arteries of the leg through a periosteal vascular network and also by two discrete vessels, the artery of the tarsal sinus arising from the dorsolateral arteries and the artery of the tarsal canal arising from the posterior tibial artery.

At dissection an artery of the tarsal sinus was found in five specimens, and an artery of the tarsal canal was found in thirteen specimens. The intra-osseous vascular pattern was visible in all specimens after decalcification, sectioning, and clearing by the Spalteholz technique. The head is supplied by vessels entering from the superior surface of the neck and the inferolateral aspect of the neck which faces the tarsal sinus. The body is mainly supplied by vessels which enter antero-inferiorly through the neck of the talus and by vessels which enter through the medial surface below the articular facet. Smaller vessels enter the body from the superior surface of the neck, the anterolateral surface of the body, and the posterior tubercle.

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Sequelae of Experimental Dislocation of a Weight-Bearing Ball-and-Socket Joint in a Young Growing Animal

Gross Alterations in Bone and Cartilage *†

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Concepts of the etiology of congenital dislocation of the hip have been evolved by a process of deduction [1], based upon normal embryological development of the hip joint and findings in infants following hip dislocation. Numerous roles have been ascribed to the associated features of congenital dislocation of the hip, chief of which are acetabular dysplasia and anteversion of the neck of the femur. Acetabular dysplasia is regarded by some as a primary cause of congenital dislocation of the hip [3,4]. Furthermore, some assign a genetic etiology to dysplasia [4].

Others [6] suggest that the associated features occur solely as a result of the dislocation. When based upon clinical observations alone, the argument as to which features are primary and which are secondary could be endless. The problem was therefore brought to the laboratory.

The object of the experiment was to determine the secondary effects of dislocating a weight-bearing ball-and-socket joint in a young growing animal.

EXPERIMENTAL METHOD

The dog was the animal of choice since it is large enough to allow relatively atraumatic dislocation of the hip and has a rapid period of growth; in addition it is relatively simple to obtain litter mates. Four litters of puppies, mostly mongrel, totaling twenty-two, were employed. The average age at the time of dislocation was three to five weeks. Under open drop anaesthesia, through a lateral approach, the right hip joint was dislocated in each of the twenty-two animals. The capsule was incised in a line paralleling the femoral neck at the anterolateral position. The ligamentum teres was completely severed in every animal. In sixteen of the animals, the head of the femur was left out of the acetabulum. A fine silk suture was placed in the capsule at the base of the neck, producing a button-hole effect and ensuring continued dislocation. In six of the puppies, the head was replaced in the acetabulum, and the capsule was repaired with fine suture. Sharp incision of the capsule and transection of the ligamentum teres were the only surgical procedures done on the hip joint. All the animals became ambulatory immediately after recovery from anaesthesia and were housed in suitable quarters with an attached dog run. The hips remained dislocated clinically with the limb in internal rotation and some adduction; roentgenographic examination was performed from four to eight weeks following dislocation.

The plan of study was to follow all of the animals through maturity in order that any secondary changes which might ordinarily be missed by early sacrifice

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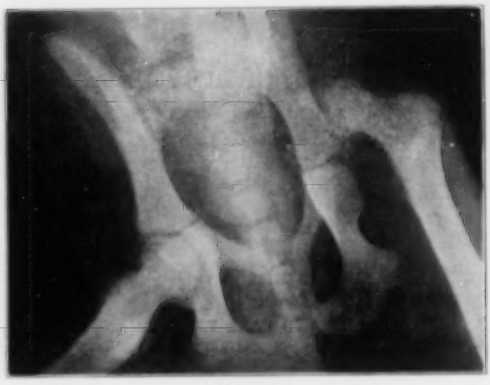

FIG. 1

FIG. 2

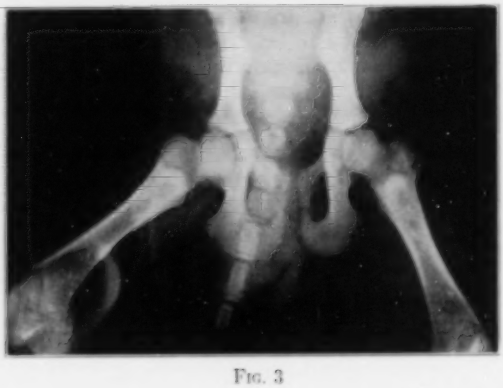

FIG. 3

Fig. 1: Roentgenogram made four weeks following dislocation in an animal seven and one-half weeks of age. Increase in acetabular index is apparent.

Fig. 2: Roentgenogram made eight weeks following dislocation in an animal eleven and one-half weeks old. There is more acetabular obliquity and incipient irregularity of the osseous margin.

Fig. 3: Roentgenogram made of control animal, eight weeks following dislocation, section of ligamentum teres, and immediate replacement of femur in the acetabulum. No acetabular changes are demonstrated.

would be noted. When full growth was attained and capital femoral epiphyseal closure effected, the animals were sacrificed.

RESULTS

As early as four weeks following dislocation, acetabular dysplasia was clearly noted in all of the experimental animals (Fig. 1). After eight weeks, the changes in the acetabulum were even more apparent (Fig. 2). In the animals in which the femoral head was replaced in the socket after dislocation and section of the ligamentum teres, little, if any, difference could be noted compared with the hip not operated upon (Fig. 3). The findings were strikingly consistent in both the experimental and control groups.

Postmortem specimens six months after dislocation showed almost unrecognizable acetabula (Fig. 4), while the control specimens showed little difference compared with the side not operated upon (Fig. 5).

Turning our attention to the changes in the head and neck, we found that the dry specimens were best suited for this study. Rather marked varus deformity was found in all sixteen dislocated hips, but no changes could be found in this regard in the dislocated hips in which the femoral head had been replaced in the acetabulum (Figs. 6-A and 6-B). The femoral heads of the dislocated hips were flattened and ovoid compared with those not operated upon and those serving as operative controls (Fig. 7).

Studies of the angle of anteversion did not show such striking changes, but in almost every instance of experimental dislocation of the hip, the angle of anteversion was less than that on the control side. This was generally about 5 to 7

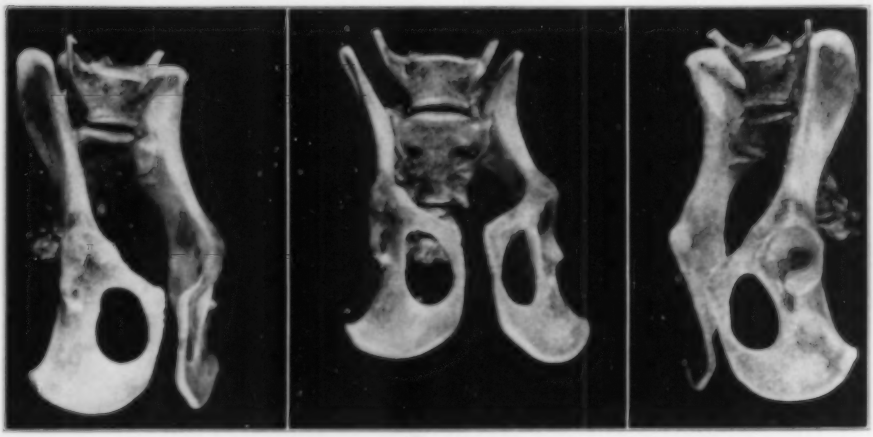

FIG. 4

Pelvis from an animal six months old showing the dysplastic acetabulum on the side operated upon.

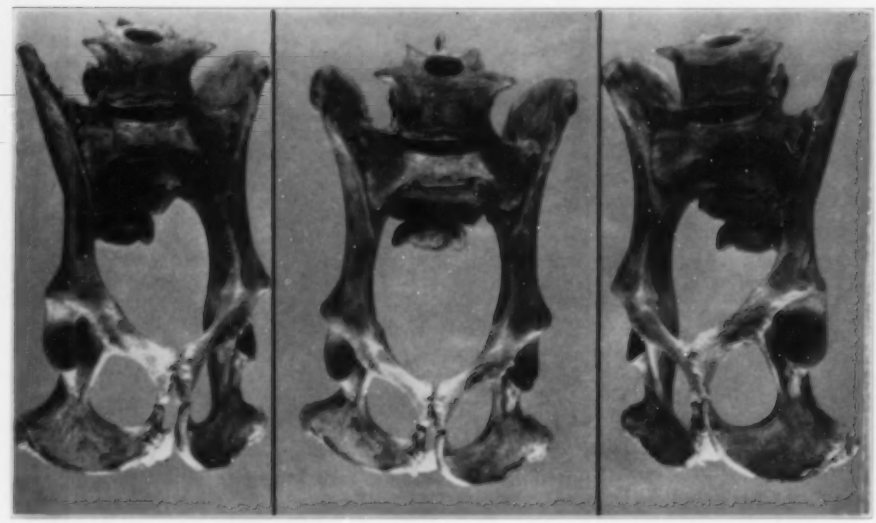

FIG. 5

Six months previously the hip was dislocated, the ligamentum teres sectioned, and the femoral head replaced in the socket. There is little, if any, difference between the side operated upon and that not in this pelvis.

degrees, except in one in which there was an increase in the angle of anteversion compared with that on the control side. The average angle of anteversion was 23 degrees in all normal hips at time of maturity.

DISCUSSION

Numerous interesting facets of this problem were anticipated: the significance of utilizing a quadruped which becomes ambulatory shortly after birth, the problem of avascular necrosis of the femoral head, the microscopic changes in the capsule, articular cartilage, and muscles, a quantitative method of recording the acetabular and femoral head changes, and the reported tendency to find dysplasia or congenital dislocation of the hip in certain breeds of dogs, notably the German shepherd [7]. Two conditions must first be assumed: (1) that aside from sharply

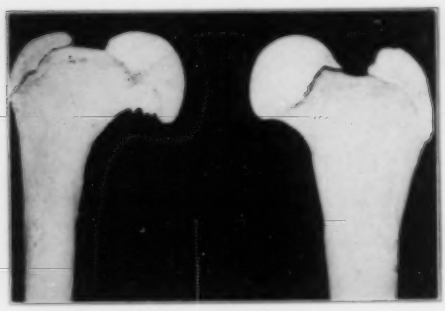

FIG. 6-A

FIG. 6-B

Fig. 6-A: Varus deformity of the neck of the femur from a dog sacrificed at age six months. The control bone is at the right.

Fig. 6-B: Femur from a dog sacrificed at age six months following dislocation, section of ligamentum teres, and replacement of femoral head in the acetabulum. There is no difference compared with the side not operated upon.

FIG. 7

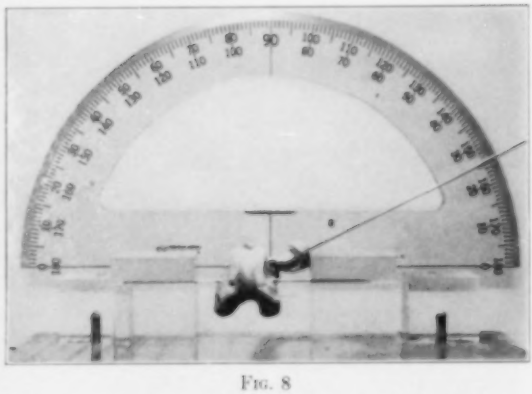

FIG. 8

Fig. 7: Appearance of femoral heads from superior aspect. The bone on the left was that dislocated.

Fig. 8: Method of determination of the angle of anteversion in this study[4].

incising the ligamentum teres, no other surgical procedure is performed within the acetabulum, and (2) that in the control animal, the identical operation is performed with the addition that the dislocation is reduced prior to closure. Disregarding any clinical significance of the effect of experimental dislocation on a weight-bearing ball-and-socket joint in a young growing animal, it follows that any change in the experimental animal not found in the control will be solely the result of the dislocation. We may therefore disregard changes in muscle, joint capsule, and blood supply, since identical handling of these structures occurred in the control and experimental animal. It is true that secondary changes in the skeletal muscles undoubtedly occur as a result of the shortening in the experimental group. To describe such changes here would only confuse the issues at hand.

If the acetabulum had identical handling in all animals, then our major interest centers upon any change that occurs. Whether the animal is a biped or quadruped is of little consequence; our objective is to report such changes in a weight-bearing ball-and-socket joint. Originally, we planned to use the so-called acetabular index as a quantitative measurement of the changes within the acetabulum, but certain other problems became more apparent as the experiments progressed. The acetabular index is fundamentally a measurement of the obliquity of the osseous portion of the acetabulum without regard for the cartilaginous constituents.

Many variables are involved in the acetabular index: the breed and age of the animal, duration of the dislocation, and the standardization of position during roentgenography. The animals were adult at the time of sacrifice. Standards for the acetabular index in infants are being challenged [2]. To our knowledge, no previous standard has been applied to dogs at any age. We therefore documented the findings photographically (Figs. 9-A and 9-B).

As for the relationship of the femoral head and neck to the shaft, we were mainly interested in whether any change in torsion occurred as a result of the dislocation in the growing phase. The factors influencing the acetabular index in dogs also obtain for the proximal end of the femur. In addition, not only are we

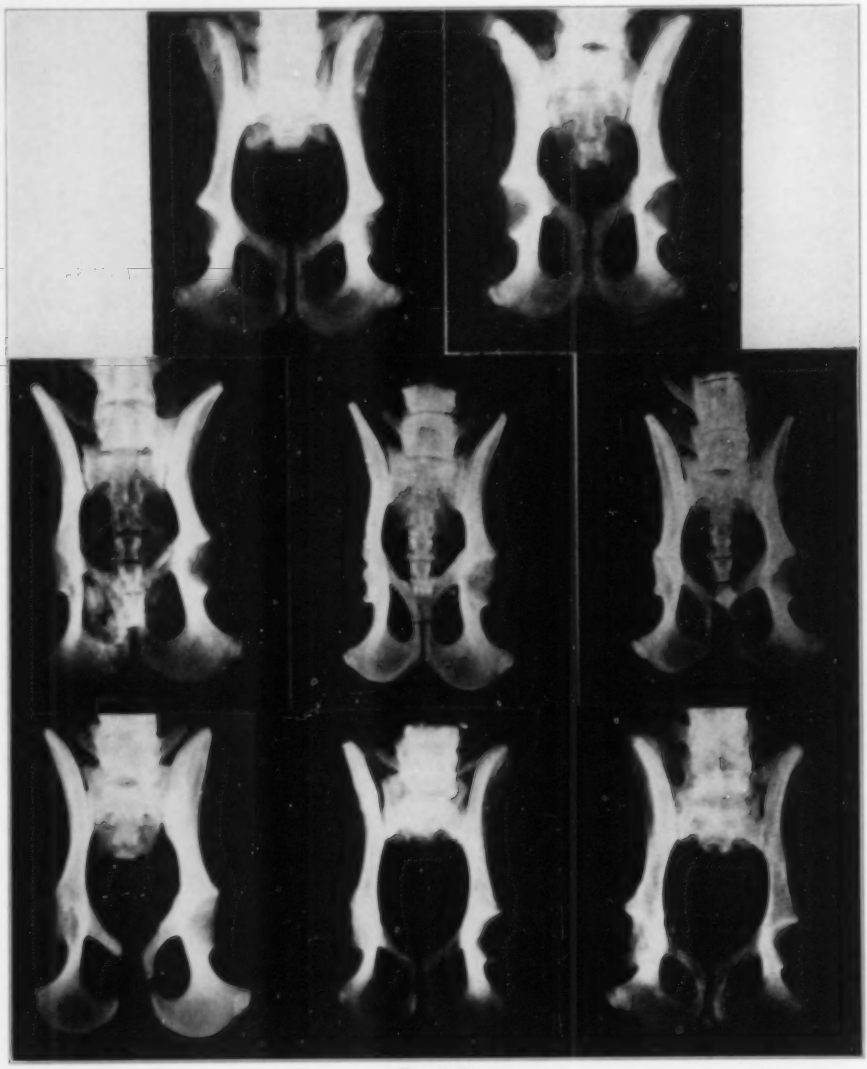

FIG. 9-A

Figs. 9-A and 9-B: Composite photographs of seventeen pelves taken from animals after sacrifice. The five specimens in the top rows are from control animals, in which the femoral head was promptly replaced in the socket. The specimens in the center and bottom rows are from animals in which the femoral head was left out of the acetabulum. Five specimens, damaged in the process of soft-tissue digestion, are not shown.

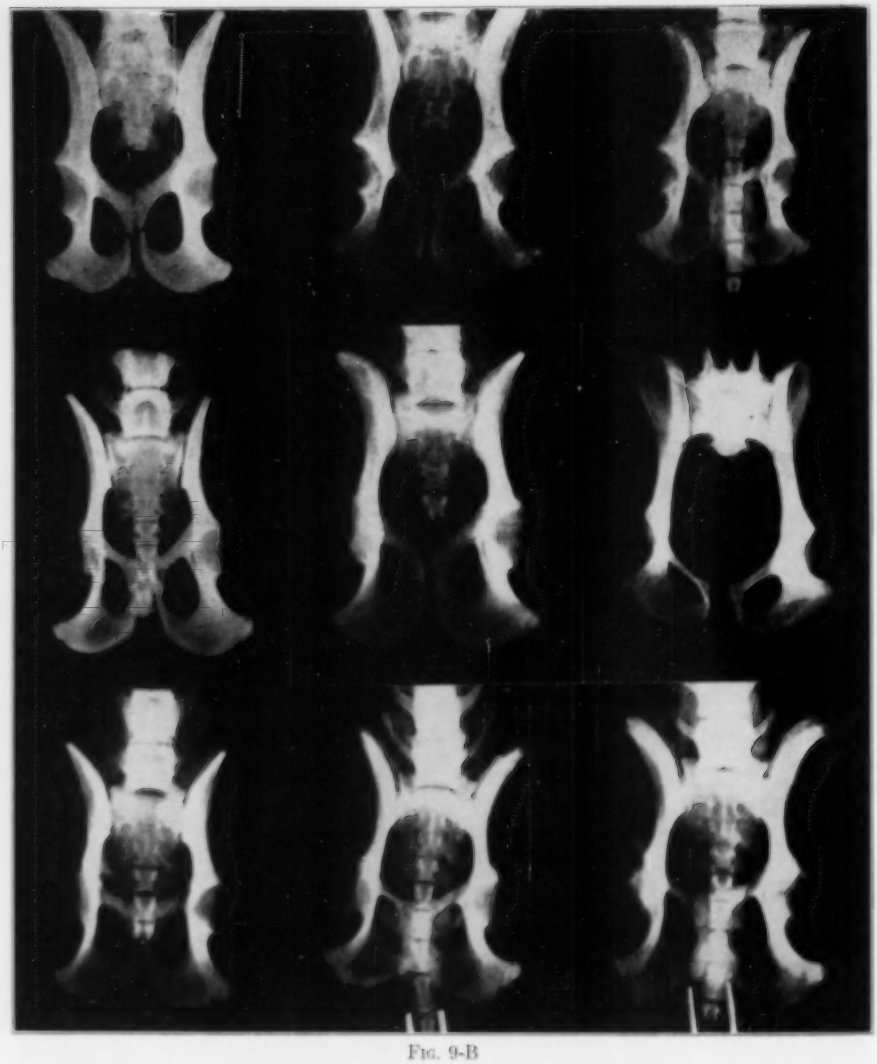

FIG. 9-B

dealing with a quadruped, but also with a quadruped which becomes ambulatory soon after birth. Any change found in the experimental animal in this regard must therefore be considered a functional adaptational change secondary to the early dislocation in this particular animal.

There is a reported high incidence of acetabular dysplasia and congenital dislocation of the hip in German shepherd dogs [7]. While this is an interesting observation, the situation is analogous to that in human patients, in whom our knowledge of the condition is based upon findings after the dislocation has taken place. From an etiological standpoint, this observation may eventually lead to important studies on the genetic aspects of this condition.

Preliminary examination of the scar formation found over the head of the femur indicates the presence of a new capsular structure complete with synovial elements, showing induction or regeneration of synovial tissue in response to a new functional demand. This phase of the work is being repeated with earlier sacrifice of the animals and better methods of localization of the exact part of

the capsule. Further elaboration of this point at present is far from the fundamental issues involved.

In this work, we have attempted to describe the gross sequelae of experimental dislocation of a weight-bearing ball-and-socket joint in a young growing animal. The emphasis was necessarily on cause and effect. Other interesting problems, here noted, evolved from this study and will be given consideration in subsequent reports.

SUMMARY

As a consequence of experimental dislocation of the hip in puppies three to five weeks old, the following changes were observed: (1) acetabular dysplasia as early as four weeks following dislocation; (2) progressive dysplasia to the point of an unrecognizable acetabulum at the time of maturity; (3) normal acetabular development following experimental dislocation and immediate relocation; (4) pronounced changes in the head and neck of the femur, manifested by varus deformity of the neck, flattening of the head, and some reduction in the angle of anteversion of the neck; and (5) no abnormalities in the head and neck in the dislocated hips in which the femora were relocated.

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Recurrent Locking of an Index Finger

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A married woman, twenty-four years old, whose work consists of wrapping bakery goods, reported to the out-patient clinic with the index finger of her left hand held in 45 degrees of flexion at the metacarpophalangeal joint. She was unable to straighten the joint either actively or passively because of a combination of pain and rigid resistance, but she could fully flex the joint without trouble.

Similar incidents had occurred during the previous three years and on these occasions she had been able to unlock the joint by a combination of distraction and rotation. Recently the incidents had become more frequent and more painful; she came to the hospital because, for the first time, she could not unlock the joint. Examination showed that the site of pain was just proximal to the metacarpophalangeal joint on the radial side of the palmar surface; pressure at this point increased the pain. There was a firm but non-voluntary resistance to attempted passive extension. The joint was stable and roentgenograms appeared normal. It was thought that the condition represented a variation of that described by Alldred in which locking was caused by a tear in the joint capsule. Operation was recommended.

Brachial block anaesthesia was used, and manipulation failed to unlock the joint. The area was explored through a radiopalmar incision. The joint capsule was intact and the locking was found to be caused by a large sesamoid bone which rubbed against a ridge

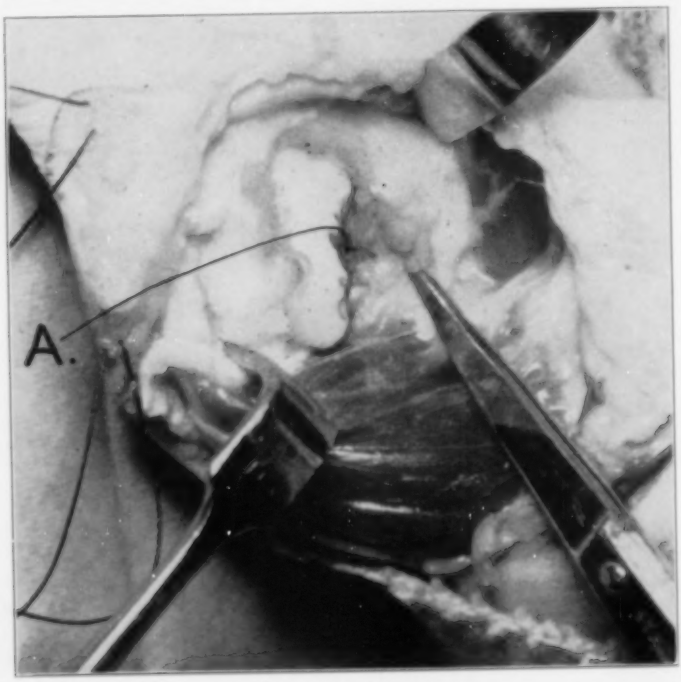

FIG. 1

This illustration is reproduced from a colored transparency. It shows the region of the palmar aspect of the head of the index metacarpal. The scissors point in the direction of finger tip. The retractor to the left (or radial side) is displacing the first dorsal interosseus muscle while the other retractor is displacing the flexor tendon sheath in an ulnar direction.

The points of the scissors lie in the roughened area from which the sesamoid bone has been excised. The irregular tissue of this area is the remanent of the palmar plate. Area *A* is the roughened ulnar side of the ridge on the palmar aspect of the metacarpal head.

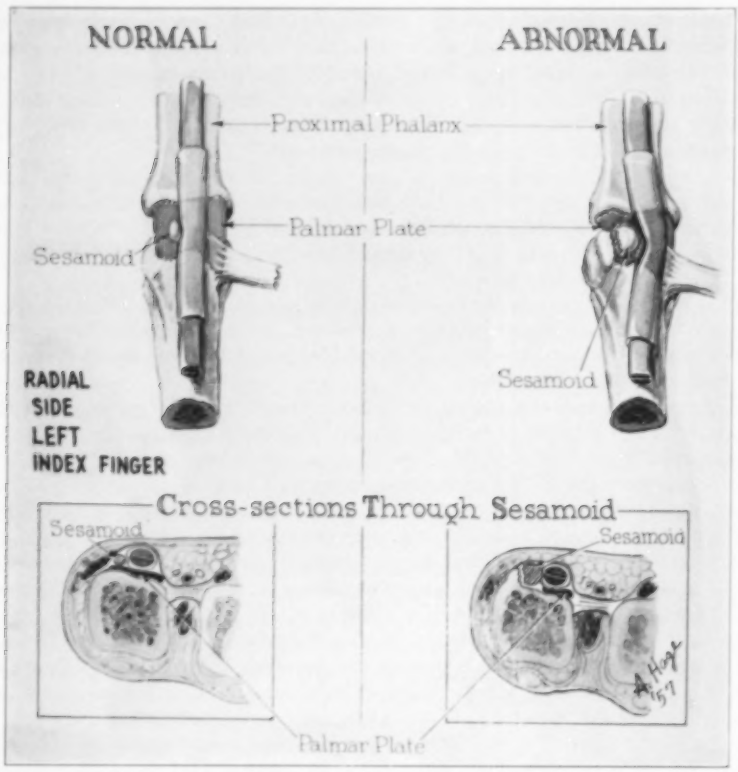

FIG. 2

The drawing illustrates how the enlarged sesamoid bone wore away the palmar plate on the radial side of the joint. The presence of the bone ridge and large sesamoid bone tends to displace the flexor tendon sheath to the ulnar side to a greater degree than normal.

on the radial side of the palmar surface of the head of the metacarpal. The contiguous surfaces of the bones were roughened and the surrounding tissues were oedematous and inflamed. If the sesamoid bone was displaced in an ulnar direction, the joint could be hyperextended to a normal degree with ease.

The sesamoid bone was excised and the ridge of bone on the metacarpal head was removed. The palmar surface of the head was smoothed and the joint capsule in this area was reconstituted by suturing together, with fine catgut, the tissue from the side of the first dorsal interosseus muscle and the flexor tendon sheath. After this, the joint could be freely hyperextended. The patient returned to work and remained free of symptoms.

DISCUSSION

Normally the sesamoid bone of the index finger lies on the radial half of the palmar plate partially replacing this cartilaginous portion of the accessory palmar ligament. The bone is attached by fibrous strands to the collateral ligament on its lateral side and the flexor tendon sheath on its medial side.

From the illustrations it can be seen how the palmar plate was replaced and how the large sesamoid bone and the adjacent flexor tendon sheath appeared to have "settled into" the metacarpal head because of the presence of the ridge on the radial side of the head. There is an exaggerated ulnar displacement of the flexor tendon sheath because of the presence of the ridge and large sesamoid bone.

The sesamoid bone was firmly attached to the remains of the palmar plate which in turn was attached to the base of the phalanx. All three structures therefore traveled as one unit throughout the range of movement of the joint.

However, the roughness on the contiguous surfaces of the ridge and sesamoid bone was so marked that when attempted extension put the structures on tension the bone surfaces were forced together producing locking of the joint. Separation of the bone surfaces by ulnar displacement of the sesamoid bone immediately allowed free extension of the joint with the sesamoid bone traveling in a proximal-distal direction as the finger extended.

Sections of the excised sesamoid bone showed it consisted of normal living bone surrounded by areas of old granulation tissue. No inflammatory cells were seen. In view of the normal anatomical site and the viability of the bone it is considered that this bone was a true sesamoid bone and not a loose body resulting from osteochondritis dissecans.

It is probable that similar cases have occurred in the past but the writer is not aware of any such cases having been reported. A note concerning the anatomy of the sesamoid bones of the hand is added because of the paucity of description in current textbooks of anatomy.

The sesamoid bones of the upper limb are found only on the palmar surface of the hand. Their number is variable. Almost constantly there are five; two at the metacarpophalangeal joint of the thumb, one at the interphalangeal joint of the thumb, and one each at the metacarpophalangeal joint of the index and little fingers. Rarely are sesamoid bones found at the metacarpophalangeal joints of the long and ring fingers and only very occasionally at the interphalangeal joints of other digits. The sesamoid bones are intimately related to the palmar plates or volar accessory ligaments and the fibrous flexor tendon sheaths. The flexor tendon sheath is attached to the under surface of the palmar plate thereby forming on the lateral side a V-shaped space in which the sesamoid bone lies. The sesamoid bone of the index finger occurs on the radial side of the flexor sheath and frequently replaces part of the thickness of both the tendon sheath and the palmar plate. When it is well developed it is oval in shape with its long axis placed in the long axis of the digit. The incidence of the sesamoid bone is given variously as between 42 to 64 per cent. It is my clinical impression that the higher figure is more likely to be true. It is interesting to note that Bizarro in a paper published in 1921 recorded that in cases in which the sesamoid bone is very small or absent, the metacarpal head may have an abnormal palmar cornual projection. It was his view that this projection took the place of the sesamoid bone.

It seems possible in this case that such a ventral projection on the metacarpal head was already present and that attrition between it and the large sesamoid bone produced sufficient roughening of the bone surfaces to allow locking to take place.

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Malignant Giant-Cell Tumor of the Ulna

Report of a Case of Eighteen Years' Duration

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INTRODUCTION

Well documented cases of malignant giant-cell tumor are rare. Murphy and Ackerman emphasized this in their recent report of thirty-one cases, including five regarded as malignant. Stewart, Coley, and Farrow reported seven cases drawn from the Bone Tumor Service of the Memorial Hospital, New York, N. Y., over a period of several years. The rarity of giant-cell tumors of all varieties may be appreciated when it is considered that Murphy's report of thirty-one cases covers a period of thirty-three years in two hospitals. Many case reports are beclouded by lack of complete data. Often roentgenograms are not available or original biopsy specimens cannot be consulted. Much of the older literature is of academic and historical interest only because of confusion as to what constitutes a giant-cell tumor. Indeed it may be stated that even today some confusion exists. There is a reluctance to classify as giant-cell tumors those that pursue a malignant course. Some pathologists who recognize varying degrees of malignancy of giant-cell tumor argue, almost to the point of obsession, that when a giant-cell tumor is or becomes malignant, a malignant tumor of different type may be superimposed upon a previously benign tumor. Stewart, Coley, and Farrow dismissed this argument with the observation that it belongs in the realm of philosophical discussion.

A review of the history of giant-cell tumor provides much information of academic interest. Over a century ago, Lebert and Virchow recognized the possibility that the giant-cell tumor, under certain circumstances, might run a malignant course. However, their material was too incompletely documented to be acceptable by modern standards. The influence of Bloodgood and also of Ewing emphasized the fundamental benign nature of the lesion. Ewing, for instance, defined giant-cell tumor as a "low grade neoplastic process, usually single, sometimes multiple, pursuing a prolonged and generally progressive course and failing to yield metastases." And again, "the fact that pulmonary metastases do not occur in the ordinary course of giant-cell tumors of bone, is one of its most remarkable features." It is certain that Ewing was not unfamiliar with malignant giant-cell tumors. It would seem however, that he favored the view that a new tumor arose in the site of a giant-cell tumor and superimposed its malignant properties upon the fundamentally benign properties of the underlying giant-cell tumor. Coley was among the first of those, who, with the benefit of modern pathological study of his cases by Ewing and Stewart, recognized that giant-cell tumors were not infrequently malignant in outcome. Indeed, Coley estimated that about 15 per cent of giant-cell tumors became malignant. He went further and insisted that giant-cell tumors could metastasize and retain the characteristics of a giant-cell tumor. Although a surgeon and not a pathologist, he took a keen interest in pathology and never operated without careful microscopic study of all sections available. He even took issue with Ewing on this matter. That Coley's views were correct and that his views were far in advance of those of his contemporaries, is borne out by the more recent observations of Murphy and Ackerman. Their remarkable Case 31 should completely dispel the notion that giant-cell tumors of bone never yield metastases. This giant-cell tumor of the lower portion of the right radius occurred in a man, forty-four years old. Roentgenographic examination revealed a giant-cell tumor,

thought to be possibly malignant. Chest roentgenograms were originally negative. Amputation was performed since study of the frozen section gave rise to the opinion that the tumor was malignant. The specimen showed that the tumor had perforated the cortex and periosteum and involved soft tissue. Microscopic examination revealed a Grade I or perhaps Grade II giant-cell tumor. Five years later, chest roentgenograms showed a solitary metastasis which was removed by segmental resection of the right lung. The microscopic diagnosis was again that of a Grade I or Grade II giant-cell tumor. It is of interest that a shell of bone had formed a kind of capsule around the tumor. In 1947, a second pulmonary metastasis developed; this was resected and presented the same microscopic picture. The patient was followed for seven years, and was reported as alive and well in 1954. This case is parallel to cases of metastasizing benign leiomyoma of the uterus. While it is true that histological examination is not always the most accurate measure of biological behavior, it is certainly, in proper hands, the best available.

Jaffe, Lichtenstein, and Portis, in their excellent review, clarified the concept of giant-cell tumor. They excluded from the category of giant-cell tumor many lesions with giant cells, such as bone cysts, chondroblastomata, and osteolytic osteogenic sarcomata with giant cells and restricted the term to a specific lesion, usually in the epiphysis. They further crystallized the concept of grading of tumors into three numerical grades (I, II, and III) to indicate increasing degrees of malignancy. A similar grading was independently in use at Memorial Hospital for years, where giant-cell tumors were classified as benign, aggressive, or malignant. Grading is based upon a careful microscopic analysis of both stroma and giant cells. Variation in the size and shape of the stromal cells and frequency of mitotic figures provide the best clue. When stromal cells are small, uniform in size and shape, and exhibit relatively few mitotic figures, the tumor is Grade I. Such tumors will also contain many giant cells with multiple nuclei, varying from twenty-five to fifty. Grade II tumors show more mitotic activity and few giant cells with fewer nuclei. One rarely counts nuclei or mitotic figures and grading is usually done by the impression method. Grade III tumors show more mitotic activity and areas where there is even more variation in size and shape of the stromal cells and nuclei and where tumor giant cells are present, as opposed to the characteristic epulis giant cells. The mere presence of osteoid tissue in a giant-cell tumor cannot, in itself, be used as a criterion of malignancy, since osteoid may be due to reaction or healing. However, osteoid in Murphy and Ackerman's case raises the question of the inviolability of the concept of pure giant-cell tumor of bone. Surely osteoid here is not reactive, although it could conceivably result from metaplasia. While the sharp circumscription of the concept of giant-cell tumor and the exclusion of variants, as advocated by Jaffe, Lichtenstein, and Portis, has great didactic value, it is questionable whether, when dealing with a tumor of unknown histogenesis, one can properly be so dogmatic. There is evidence in the literature of a return to the old concept of variants which reached a most eloquent expression in the book published by Geschickter and Copeland. This concept, which parallels that advocated by Johnson, indicates that giant-cell tumor is one of the many tumors of bone tissue and that it arises from mesenchymal cells, and that mesenchymal cells of all types are potentially in equilibrium with other types of mesenchymal cells.

The value of histological grading on the other hand has been seriously questioned by many other experienced pathologists. Tumors designated as Grade I have been known to run a malignant course. The tendency is to acknowledge that grading may be of value but must be qualified by other considerations.

The present case is reported because it represents a giant-cell tumor pursuing a malignant course without benefit of prior therapy. In many of the cases reported in the literature, a giant-cell tumor became malignant after a period of many years following repeated curettage, repeated courses of roentgen ther-

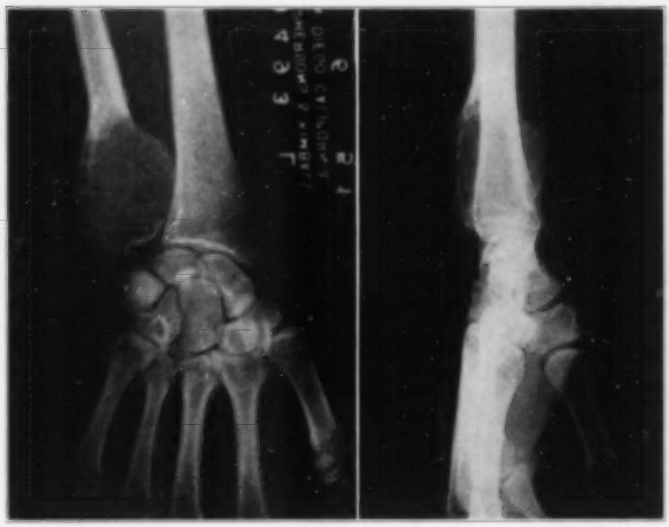

FIG. 1

Roentgenograms of left wrist, made July 6, 1951. Note the large, expansile, lytic lesion of the distal portion of the ulna.

apy, or combinations of both. Coley was most emphatic in denouncing combined roentgen therapy and surgery as treatment that was virtually tending to cause the tumor to become malignant. Sarcoma followed radon-seed therapy of a giant-cell tumor, a form of treatment which was used in the early days of the twentieth century. Coley considered this form of bone cancer identical with bone cancer which developed in the radium-dial workers reported by Martland. Kleinberg, who reported a malignant giant-cell tumor, introduced his paper by stating that only treated giant-cell tumors became malignant.

A white woman, thirty-nine years old, was first seen on July 6, 1951, complaining of pain in the left wrist. She had noted an enlargement of the wrist for eighteen years, and believed that this enlargement followed a fall on the hand. She had no significant discomfort in the wrist until two months prior to her first visit, when she had hyperextended her left wrist lifting the lid of a freezer. Following this incident, the lesion had enlarged and had become increasingly painful, especially at night. She had consulted another orthopaedic surgeon who had recommended amputation of her arm. She stated emphatically that she was not interested in amputation, and that she would not accept amputation, regardless of the consequences. She denied previous roentgen treatment.

This woman had had no serious illness or disability. She had had a thorough physical check-up at a Naval Hospital eight years before, when she had been told that she had a giant-cell tumor in the left forearm. She stated that she was instructed to have no treatment at that time since the tumor was asymptomatic.

Examination revealed a well developed woman of good posture in no acute distress. The general physical examination was entirely within normal [illegible]. In the left upper extremity there was a large mass in the distal third of the ulna, one-half inch above the wrist joint. This mass was firm, smooth, and apparently well demarcated. There was moderate tenderness of the mass and there was no regional or general lymphadenopathy.

Figure 1 is a roentgenogram of the left wrist made on July 6, 1951, showing a large expansile lesion in the distal portion of the ulna, which was considered characteristic of giant-cell tumor.

It was recommended that the patient be admitted to the hospital for resection of the distal portion of the ulna. For personal reasons, the patient refused to go into the hospital until October 23, 1951, at which time the distal one-third of the ulna was resected. The patient had an uneventful convalescence.

The patient was followed until January 24, 1952, when she had excellent use of the forearm and hand. She was instructed to return in three months, but failed to return until July 14, 1955. At this time she complained of lumps on her right elbow and forehead. She stated she had been perfectly well until seven weeks prior to this examination, when

FIG. 2

FIG. 3

Fig. 2: Roentgenograms of right elbow, made July 14, 1955. Note the large osteolytic lesions involving the medial epicondyle of the humerus.

Fig. 3: Roentgenograms made July 14, 1955, of left wrist showing operative defect. Note the small lytic lesion in the left radius and the absence of local recurrence.

she had bumped her forehead on a cupboard door. Directly after this she noted a small nodule on the forehead. Four weeks prior to re-examination, she bumped the right elbow, and at that time she had noted an enlargement over the right elbow. At both of these sites she complained of tenderness on palpation. Her general health had been excellent. She did admit to a cough which she stated had been present for years without significant change. This cough was unproductive and minor. There had been no weight loss and her general health and comfort were excellent.

Re-examination at this time revealed a small nodule below the hairline of the forehead which was soft, non-movable, and not adherent to the skin. There was an ill defined enlargement with a soft mass over the medial epicondyle of the right humerus. No regional lymphadenopathy was noted. Roentgenograms were made on July 14, 1955, of the skull, right elbow (Fig. 2), and left forearm (Fig. 3). In the right humeral medial epicondyle there was an osteolytic lesion with almost complete dissolution of the cortex and, in the distal portion of the left radius there were small osteolytic lesions. There was also an osteolytic lesion of the frontal bone.

The patient was rehospitalized and roentgenograms revealed two large ovoid masses in the lungs. One mass in the right middle lobe was ten centimeters in diamter and the other, in the anterior basilar aspect of the left upper lobe, was a spherical mass, three centimeters in diameter.

The complete laboratory findings were as follows. On July 19, 1955, the red blood cell count was 3,560,000; hemoglobin, 9.3 grams per 100 milliliters (64 per cent). The white blood cell count was 9,750, with 82 per cent segmented cells, 15 per cent lymphocytes, and 3 per cent monocytes. The sedimentation rate (Wintrobe) corrected to 14 millimeters per hour. The hematocrit was 34 volumes per cent.

The urine was straw-colored. Urinalysis was negative for albumin and sugar; epithelial cells were noted on the smear.

On July 20, the Bence Jones test for protein was negative. Kahn test was negative.

On July 21, the alkaline phosphatase was 2.9 Bodansky units; calcium, 10.6 milligrams per 100 cubic centimeters; inorganic phosphorus, 4.1 milligrams per 100 cubic centimeters; total protein, 6.4 grams per 100 cubic centimeters; albumin, 4.0 grams per 100 cubic centimeters; and globulin, 2.4 grams per 100 cubic centimeters, with an albumin-globulin ratio of 1.65.

Papanicolaou's stain of the sputum was negative for malignant cells. Study of the marrow showed it to be within normal limits.

On July 20, 1955, biopsy was done of the lesion of the medial epicondyle of the right humerus. On exposure of the origin of the flexors of the forearm, a small mass could be felt deep in these muscles. The muscles were detached from their insertion by sharp dissection and, on turning back the muscles, a soft tumor was exposed. The surrounding bone

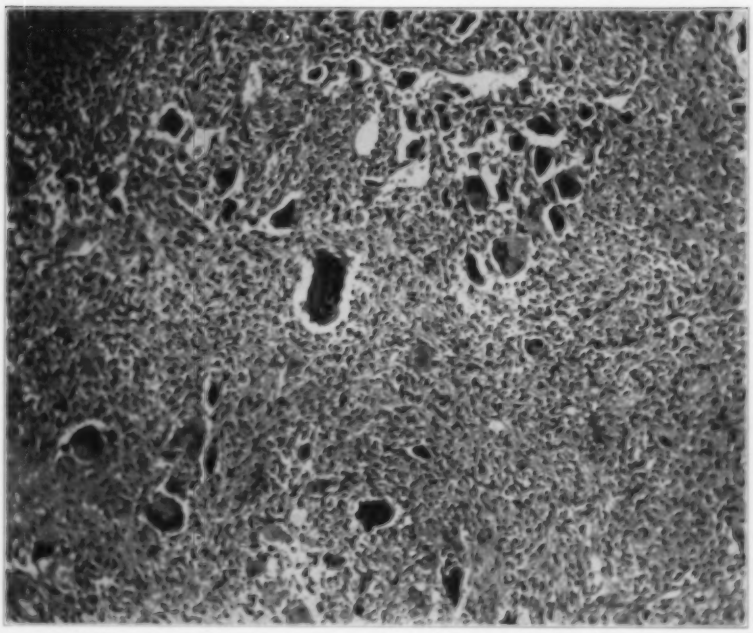

FIG. 4

Photomicrograph (× 97) of original giant-cell tumor, made October 23, 1951, showing a representative area of the lesion.

was completely disintegrated. The tissue removed was whitish-gray with streaks of red friable tissue which was removed with the curette without difficulty. Hemostasis was secured and the wound closed. After completion of the biopsy, the pathologist obtained a small plug of sternal-bone marrow for marrow study. The complete pathological reports are as follows.

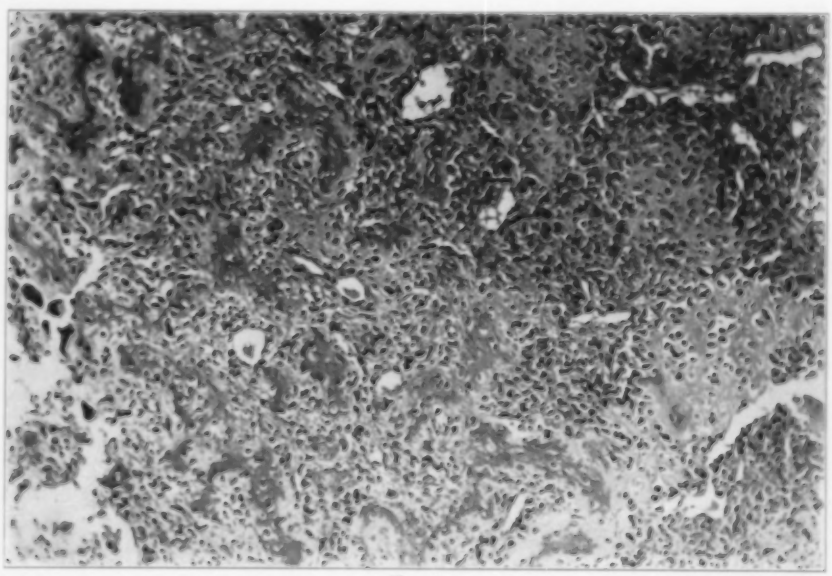

FIG. 5

Photomicrograph (× 93) made October 23, 1951, showing an area of osteoid in the original tumor.

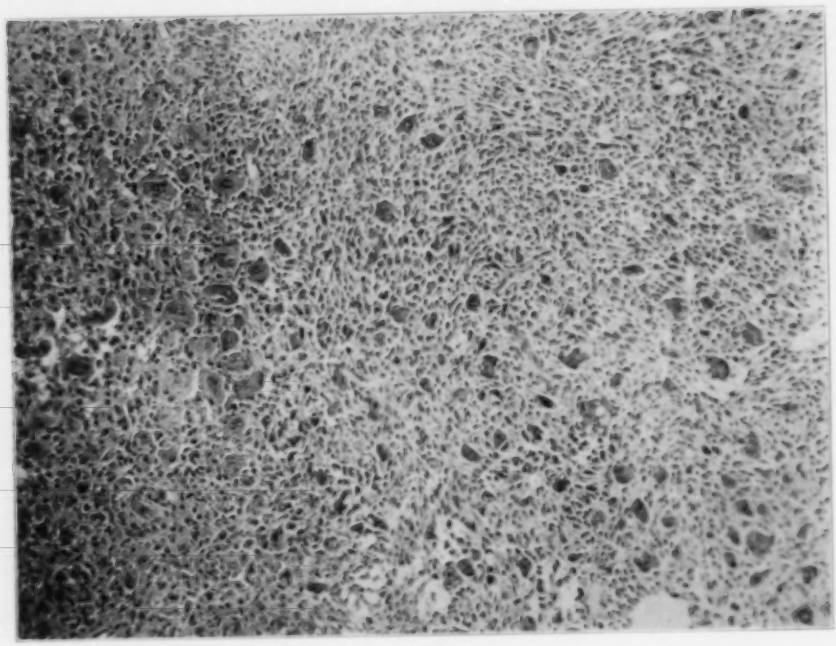

FIG. 6

Photomicrograph (× 85) of section of metastatic giant-cell tumor of right olecranon, made July 21, 1955.

The original specimen resected from the lower portion of the left ulna consisted of a tumor weighing 57.5 grams. This mass had a vertical measurement of eight centimeters. The lower end showed a small area of articular cartilage covering the distal end of the bone. The proximal end had the appearance of a segment of a small bone, typical of the ulna, three centimeters in length and 0.8 centimeter in diameter, containing friable, fatty, medullary tissue. On sagittal section, the cystic portion was seen to consist of a thin outer shell of bone about one millimeter thick, within which there was an internal tumor substance, having the consistency and color of custard. On section, multiple small spicules of bone were encountered throughout the tumor. The custard-like consistency of the interior of the tumor was uniform except in the periphery, where the consistency was that of organized hemorrhage. The shell of cortex surrounding the tumor had a parchment-like consistency.

Sections were prepared of the original tumor (Pathology No. 4813-51) across the cystic space. Microscopic studies showed the periosteum beneath which there was subperiosteal new-bone formation characterized by the presence of atypical, wavy, irregular bone trabeculae. The tumor extended to the periosteum and the appearance was somewhat varied in different areas. The tumor was composed of a groundwork of small, blunt stromal cells. The nuclei varied somewhat in size and shape, some being ovoid, others vesicular, some slightly elongated. Most of the nuclei contained prominent central nucleoli. Mitotic figures were not numerous, there being approximately one in every two or three high-power fields. Giant cells contained from four to forty nuclei with an average of about twenty. The nuclei of the giant cells were indistinguishable from the stromal cells. The varied size and shape of the stromal cells indicated a Grade II tumor. Not only in the edges, but scattered through the center of the tumor, there were areas where the stroma was condensed to form trabeculae of osteoid. This osteoid was characterized by the presence of dense plexiform trabeculae of collagenous-like substance surrounded by stromal cells. In some areas, the stromal cells surrounded the denser trabeculae in a manner indistinguishable from osteoblasts. Elsewhere, the large zones of tumor were completely lacking in osteoid and were composed merely of blunt stromal cells and the giant cells. No chondroid elements were seen. Perforation of the cortex was not noted or demonstrated (Figs. 4 and 5). The diagnosis was giant-cell tumor, Grade II or III.

The material taken by curettage from the region of the right olecranon on July 20, 1955, consisted of 3.5 grams of soft tumor fragments. Sections of this material (Pathology No. 3772-55) showed a tumor which was completely lacking in osteoid. Giant cells were

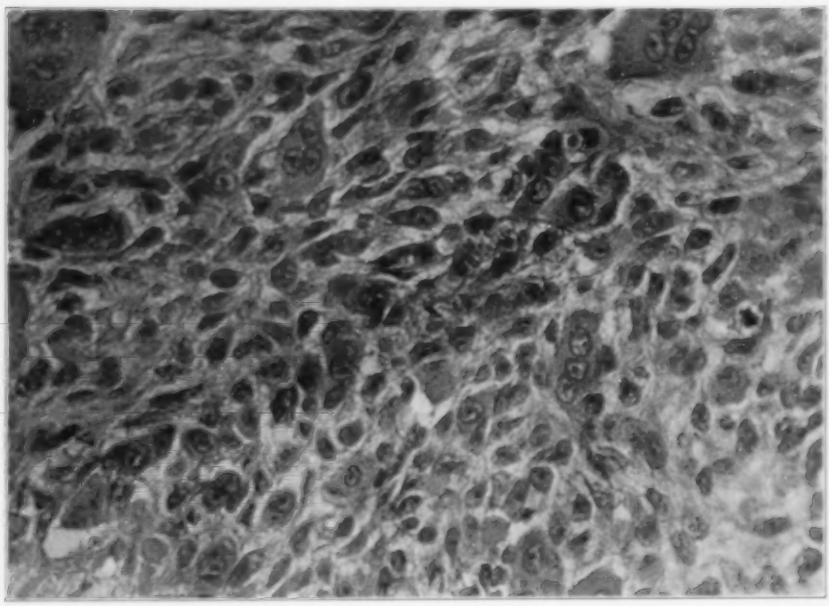

FIG. 7

High-power photomicrograph (× 330) of same section as in Fig. 6.

the most prominent feature of the tumor and averaged about forty per high-power field. The nuclei in the giant cells varied from four to forty and were centrally placed and identical with the nuclei of the stromal cells. The stroma was composed of blunt spindle cells and had the characteristic vascularity of giant-cell tumor. The mitotic figures averaged about two per high-power field (Figs. 6 and 7). The diagnosis was giant-cell tumor, Grade III.

A small amount of material taken by aspiration from the sternal marrow showed a tiny particle of tumor tissue containing stromal cells and giant cells sufficient to permit a diagnosis of giant-cell tumor. The diagnosis in this instance was a small focus of metastatic giant-cell tumor, Grade III.

The patient was given intensive x-ray irradiation which failed to have any effect on the tumor of the forearm or the right elbow. An osteolytic lesion developed in the first cervical vertebra, demonstrable by roentgenogram. The patient expired suddenly on October 4, 1955, presumably from an intracranial lesion. Permission for autopsy was refused.

DISCUSSION

The mere addition to the literature of another case of malignant giant-cell tumor would serve little purpose. In the present case, the tumor became malignant without the complicating factor of prior treatment. In fact, the prolonged neglect of therapy may have contributed to the malignant change. It was suggested that the tumor was not a giant-cell tumor, but was an osteolytic osteogenic sarcoma. Such an argument strikes the authors as incredible. The tumor was known to have existed for eighteen years without therapy of any kind. It occupied an epiphyseal location; it possessed the characteristic roentgenographic appearance. The contention that it was an osteogenic sarcoma was based on the presence of osteoid in the margins of the tumor. Admittedly the presence of osteoid in a giant-cell tumor may give rise to the fear that the tumor is an aggressive or, perhaps, a malignant variant; but it does not convert a giant-cell tumor into an osteolytic osteogenic sarcoma. One is forced to the realization, however harmful it may be from a didactic standpoint, that there is indeed a gradual spectrum of changes from the benign non-ossifying fibroma of bone which has giant-cell features to the osteolytic osteogenic sarcoma of bone; further, the same elements, mesenchymal cells, fibroblasts, osteoblasts, and osteoclasts, are present

in all of these. Interest in the present tumor is heightened since the metastases maintained the character of a giant-cell tumor. In many of the reported cases, a giant-cell tumor became malignant by the development of spindle-cell sarcomata, essentially indistinguishable from fibrosarcoma. Stewart and associates referred to them as "granulation tissue sarcoma." Still others evolve as osteogenic sarcomata producing tumor bone, osteoid, and chondroid elements. In the present case, however, the giant-cell character was maintained in the metastases to other bones.

NOTE: The authors wish to acknowledge their indebtedness to Fraser L. MacPherson, M.D., for permission to report the case and for many helpful suggestions and criticism.

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Chondrosarcoma of the Small Bones of the Hand

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Chondrosarcoma of the small bones of the hand is rare. In an analysis of 1,000 bone tumors Christensen, in 1925, reported three malignant osteogenic tumors in the small bones of the hand but did not differentiate between osteosarcoma and chondrosarcoma. Geschickter and Copeland, in reviewing 239 cases of chondrosarcoma, did not report a single case occurring in the hand. Up to 1939, of 1,200 bone tumors seen at the Memorial Hospital and the Hospital for the Ruptured and Crippled only twenty tumors in the bones of the hand were found. Of these only four were malignant and none were chondrosarcoma. Three were osteosarcomata and one was a metastatic tumor. An extensive survey of the literature at that time produced only 136 tumors of the bones of the hand; no chondrosarcoma was listed [2]. The first mention of chondrosarcoma in the small bones of the hand was in 1943 when Lichtenstein and Jaffe wrote: "We have 1 case of chondrosarcoma developing apparently *de novo* in a short tubular bone, specifically, the basal phalanx of a finger (rare location)." The following year Cruickshank reported a case of chondrosarcoma of the middle phalanx of the long finger of the left hand. Cutaneous metastasis proved by biopsy and pulmonary metastasis proved by roentgenograms later developed. In 1947, Morton and Mider reported two cases of chondrosarcoma—one arising in the basal phalanx of the long finger and one in the proximal phalanx of the ring finger. In 1954, Coley and Higinbotham [3] described a chondrosarcoma involving the fourth metacarpal. They believed that it arose from a malignant alteration in a pre-existing benign enchondroma. Of 212 chondrosarcomata seen at the Mayo Clinic and recently reported by Dahlin and Henderson, only two were located in the hand. One was in the distal phalanx of the thumb and the other in the pisiform bone. Earlier, Shellito and Dockerty, reporting experiences with cartilaginous tumors of the hand seen from 1908 to 1945 at the Mayo Clinic, found only one malignant tumor, a chondromyxosarcoma, among forty-two lesions. They stated that this occurred in a patient who had been operated upon five times at two-year intervals for a recurring benign chondroma; it was not until the fifth operation that a diagnosis of low-grade malignant tumor could be made. This lesion was later reviewed. Since it was not believed to be of cartilaginous origin, it was not included in the Mayo Clinic series of chondrosarcomata. Posch, in 1956, writing on tumors of the hand, mentioned a case of chondrosarcoma occurring in the proximal phalanx of the long finger in a colored man, sixty-eight years old.

To the eight reported cases of chondrosarcoma of the small bones of the hand, we are adding a ninth case in a patient who was recently treated at Barnes Hospital. Table I gives a summary of the reported cases of chondrosarcoma of the small bones of the hand.

J.B.B., a white female (B.H. #124993), fifty-nine years old, was first seen at another hospital nine months previously because of a tender swelling of the dorsum of the left hand. Roentgenograms (Fig. 1) showed a cystic lesion of the third metacarpal head and scattered areas of mottled lucency in the proximal portion of the metacarpal shaft. It was believed that this represented a benign tumor. It was removed by curettage. No bone graft was employed. Histological examination of the material curetted was reported as being compatible with an enchondroma. After the first operation the patient continued to have a slightly tender swelling of the dorsum of the left hand. Figure 2 shows the roentgenogram of the left hand three months postoperatively. Two months prior to her admission to Barnes Hospital the swelling of the left hand

TABLE I

SUMMARY OF REPORTED CASES OF CHONDROSARCOMA OF THE SMALL BONES OF THE HAND

Author	Age (*Years*)	Sex	Presenting Complaint	Location	Treatment	Results
Lichtenstein and Jaffe	Unknown	Unknown	Unknown	Proximal phalanx	Unknown	Unknown
Cruickshank	66	Male	Swelling	Middle phalanx, long finger	Amputation, metacarpophalangeal joint	Pulmonary and cutaneous metastasis 25 months postoperatively
Morton and Mider	58	Male	Painless lump with gradual increase in size for 2 months	Basal phalanx, long finger	Amputation through metacarpal head	Well without evidence of tumor 8 years postoperatively
Morton and Mider	53	Male	Painful swelling	Proximal phalanx, ring finger	Amputation at metacarpophalangeal joint	Well 9 years postoperatively
Coley and Higinbotham [3]	53	Female	22-month history; original biopsy specimen reported as benign	Fourth metacarpal	Partial amputation of hand	Alive with bilateral pulmonary metastasis
Dahlin and Henderson [7, 8]	38	Male	Local pain and swelling for 2 years	Pisiform	Local excision, recurrence 13 years later treated by excision	Follow-up unknown
Dahlin and Henderson [7, 8]	62	Female	Pain in thumb for 4 years	Distal phalanx, thumb	Amputation through proximal phalanx	Well 29 months postoperatively
Posch	68	Male		Proximal phalanx, long finger	Ray amputation	Well 12 months postoperatively
Lansche and Spjut	59	Female	Painful swelling, biopsy specimen nine months previously reported as enchondroma	Third metacarpal	Ray amputation	Well 13 months postoperatively

FIG. 1

FIG. 2

FIG. 3

Fig. 1: Roentgenogram shows generalized osteoporosis of the bones of the left hand and wrist. There is widening of the entire shaft of the third metacarpal particularly notable at the distal portion with an increased mottled lucency in the proximal half of the shaft. Erosion of the internal aspects of the cortex is present in the distal third of the third metacarpal (W.U. Ill. #57-5152).

Fig. 2: Roentgenogram of the left hand three months after the first operation. The expansile cystic lesion of the third metacarpal head is essentially unchanged except for periosteal reaction at the operative site. The mottled lucency of the proximal portion of the third metacarpal shaft is unchanged (W.U. Ill. #57-5123).

Fig. 3: Roentgenogram of the left hand just prior to the second operation, nine months after the first operation. The cystic lesion of the third metacarpal head had enlarged and extended into the adjacent soft tissues. The mottled lucency of the proximal half of the third metacarpal shaft is unchanged when compared with the original roentgenograms (W.U. Ill. #57-5154).

had started to enlarge rapidly and had become painful. During the last month the pain had become constant. Roentgenograms made on admission (Fig. 3) showed an expanded cystic lesion of the third metacarpal head without interval change in the scattered areas of mottled lucency in the metacarpal shaft. There had been a loss of five pounds of weight during the last month. Otherwise the patient was in good health.

The important physical findings were limited to the left hand and revealed a smooth, slightly tender bone mass, three by four centimeters in size attached to the distal portion of the third metacarpal. The overlying skin was free, and there was no evidence of infection. No palpable lymph nodes were present in the axillary or epitrochlear regions. Routine laboratory work and tests to determine the levels of serum calcium, serum phosphorus, alkaline phosphatase, total and fractional proteins, and the sedimentation rate were within normal limits. The roentgenogram of the chest was negative for evidence of pulmonary metastasis.

Preoperatively chondrosarcoma was suspected, and an *en bloc* amputation of the third finger and metacarpal through the third metacarpocapitate joint was performed. The postoperative course was uneventful. The gross specimen (Fig. 4) revealed a cartilaginous tumor two by 1.25 centimeters in size which had expanded the distal third of the metacarpal shaft, eroded the cortex, and extended into the adjacent soft tissues. Microscopically the tumor (Fig. 5) was composed of cartilage cells which varied in size and shape, had bizarre swollen nuclei, and nuclei with suggestive mitotic figures. Multinucleated cartilage cells and lack of a normal maturation pattern were noted. This histological picture confirmed the diagnosis of chondrosarcoma. Sections cut from deeper levels of the material curetted at the first operation,

FIG. 4

Photograph of the gross specimen shows a cartilaginous tumor which has expanded the distal third of the metacarpal, eroded the cortex, and extended into the adjacent soft tissues. A second, but completely separate, cartilaginous tumor is present in the proximal portion of the metacarpal. The bone between the two cartilaginous tumors appears normal (W.U. Ill. #57-4832).

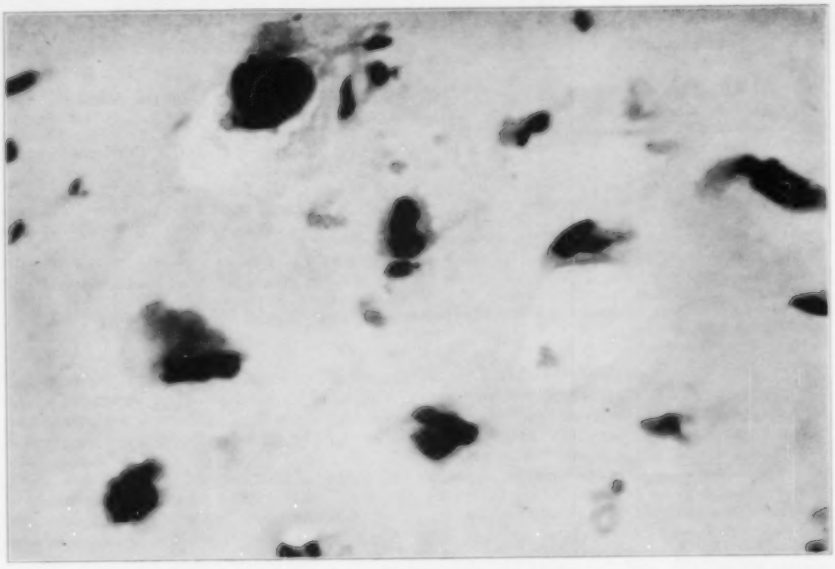

FIG. 5

The resected specimen of the lesion in the metacarpal head shows changes similar to those of the biopsy specimen, poorly differentiated chondrosarcoma (hematoxylin and eosin, × 600) (S.P. #57-5026A).

nine months previously, were similar to the present sections and, in retrospect, are also considered to be chondrosarcoma (Fig. 6). A second cartilaginous tumor was present in the proximal portion of the metacarpal and was histologically proved benign and totally unlike the distal tumor. The second cartilaginous tumor (Fig. 7) showed mature fairly well oriented calcifying cartilage and was thought to be enchondroma.

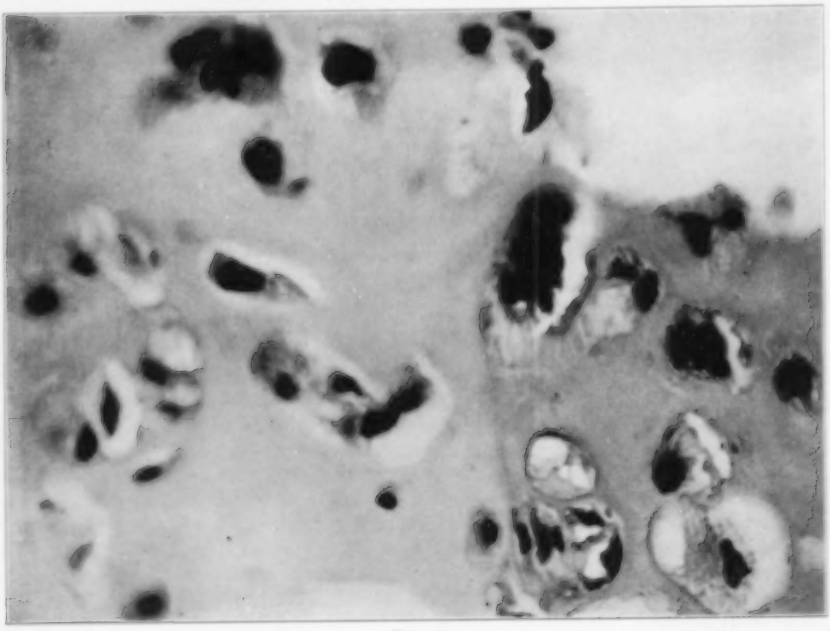

FIG. 6

Re-cut, deeper sections of the material curetted from the third metacarpal head in the first operation demonstrate the nuclear changes and multinucleated cells of chondrosarcoma (hematoxylin and eosin, × 630) (S.P. #57-5026B).

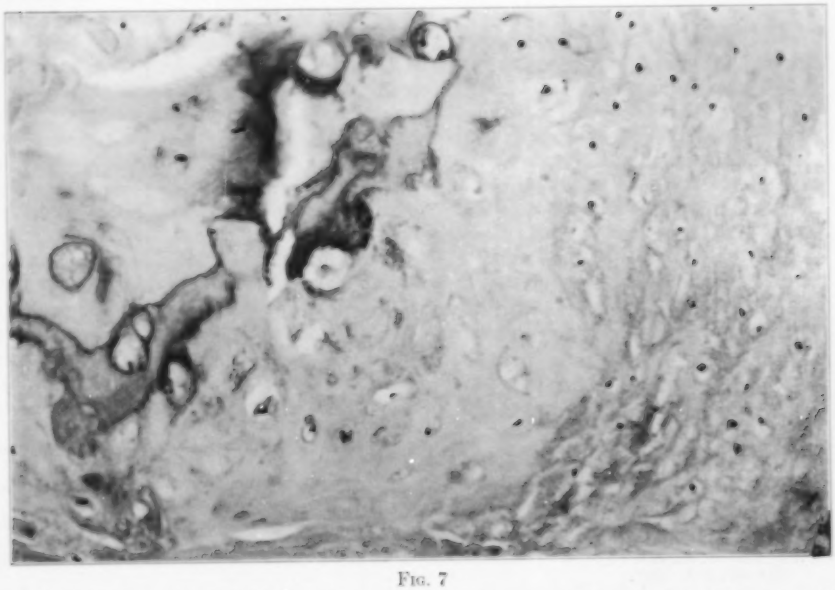

FIG. 7

This shows an area of the cartilaginous tumor from the proximal portion of the metacarpal. Here one observes mature, calcifying, fairly well oriented cartilage, compatible with enchondroma (hematoxylin and eosin, × 172) (S.P. #57-5026C).

TABLE II

LOCATIONS OF SIXTY-SIX ENCHONDROMATA IN THE HAND

Author	Finger						Metacarpal						
	Thumb	Index	Long	Ring	Little	Unknown	Thumb	Index	Long	Ring	Little	Unknown	Total
Geschickter and Copeland	6	7	6	12	6	5			5		2	3	52
Lansche and Spjut	1		3	2	1	4			2	1			14
Total	7	7	9	14	7	9			7	1	2	3	66

DISCUSSION

It is often stated that cartilaginous lesions in the small bones of the hand are benign while those of the long bones, pelvis, and shoulder girdle are often malignant. That malignant transformation occurs in a previously benign enchondroma is one explanation often advanced for the etiology of central chondrosarcoma. Enchondromata are most common in the small bones of the hand and especially in the phalanges. Jaffe and Lichtenstein reported eighteen of twenty-eight enchondromata located in the small bones of the hand. Geschickter and Copeland found enchondromata located in the phalanges in forty-two and in the metacarpals in ten of 110 patients. Coley and Santoro listed enchondromata in nine phalanges and two metacarpals in twenty-four cases in twenty-two patients. Of the twenty-four histologically proved enchondromata seen at Barnes Hospital, fourteen were located in the hand, eleven in the phalanges, and three in the metacarpals.

Why, if enchondromata are more common in the small bones of the hand and especially in the phalanges, is chondrosarcoma of the small bones of the hand so rare? When it does occur in the hand, chondrosarcoma has a tendency to occur in the phalanges where enchondromata are more common. Six of the nine chondrosarcomata (Table I) occurred in phalanges. An interesting observation is that five of the nine cases of chondrosarcoma of the hand were located in the long finger. However, enchondromata located in the hand have a fairly uniform distribution (Table II).

Only one of the nine cases of chondrosarcoma involved a carpal bone [7]; this was located in the pisiform bone. The lesion was treated by local excision, recurred thirteen years later, and was again excised. Subsequent follow-up of this patient is not known. Enchondromata, likewise, are very rare in the carpal bones. The only reported enchondroma occurring in the carpal bones was listed by Dahlin [6]. The exact location was not mentioned.

In our patient, there were two cartilaginous lesions in the third metacarpal. The one located in the metacarpal head was malignant while the one in the metacarpal base was benign. These lesions were separated by normal bone. Does this represent a malignant transformation of a previously benign enchondroma? We do not believe that we have definite evidence to support this idea, but it is an interesting postulation.

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Bilateral Recurrent Dislocations of the Superior Tibiofibular Joint with Peroneal-Nerve Palsy

A Case Summary

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The proximal tibiofibular articulation is an arthrodial joint that possesses synovial membrane and articular cartilage. The joint capsule is strongly reinforced anteriorly and posteriorly by fibrous ligaments which bind the fibula to the posterolateral aspect of the lateral tibial condyle. It is because of its protected location and strong ligamentous support[4] that dislocation of the proximal tibiofibular joint is so rarely encountered.

Lyle reviewed forty-one cases of superior tibiofibular diastasis in 1925; by 1946 Butler could add only thirteen more. Since that time Vitt reported an additional four cases occurring in paratroopers. Recently other authors[3,7] added four more case studies.

The majority of patients were young adults and the representation of sex was about equal. The youngest patient was an eighteen-month-old infant[5] and the oldest a sixty-eight-year-old woman[7].

Tibiofibular dislocation may be primarily due to trauma or secondarily due to disturbances in growth, acute osteomyelitis, complicated fractures about the upper end of the tibia and fibula, or a complication in amputation stumps[5]. Four types of dislocation have been described with the fibular articular facet of the tibia being used as a reference point: anterior, posterior, upward, and double. Double dislocation refers to a simultaneous disruption of both the superior and inferior tibiofibular articulations.

FIG. 1

Roentgenogram of superior tibiofibular articulations seven years after insertion of metal screws. Areas of bone resorption are apparent.

FIG. 2

Roentgenogram after excision of proximal portion of the fibulae and removal of screws.

The anterior dislocation is by far the most common—it occurs twice as often as posterior dislocation. Upward and double dislocations are infrequent. Posterior dislocation leads to a high rate of morbidity[6] since a significant percentage tend to result in a chronic condition which may be due to the difficulty encountered in maintaining reduction. Two cases of peroneal-nerve palsy have been recorded[5] and both were associated with posterior dislocation.

The following report of a case of diastasis of the proximal tibiofibular joint is unprecedented because the diastasis occurred spontaneously and was in no way associated with trauma. Furthermore, the case is unique in that the diastasis was bilateral and recurrent and was associated with palsy of both common peroneal nerves.

D. B. H., a white female, twenty-seven years old, noticed when she was fifteen, a spontaneous protrusion at the outer aspect of the right knee just below the joint line. The patient said that there was mild discomfort in the area of the knee and some tingling in the affected leg but there was no frank pain. The protrusion reduced itself spontaneously. The patient was not aware of any muscular weakness or neurological disturbance before the age of fifteen. The episode at that time was the first in the pattern of frequent and repeated dislocation of the proximal portion of the fibula. This condition soon became bilateral. The patient further revealed that these dislocations were always posterior; they were precipitated by toeing-in and relieved by toeing-out. She did not consult a physician, as her malady in no way interfered with her habits of living.

In December 1949, at the age of nineteen, the patient experienced a spontaneous dislocation of the right fibular head which she could not reduce. Talipes equinovarus of the right foot, accompanied by a dull ache in the leg, developed almost simultaneously. She was unable to restore the foot voluntarily to its neutral position and for the next two weeks walked on the outside of her foot. The patient then consulted a physician who prescribed a leg brace.

After three months, however, the brace became worn and was discarded. Internal fixation of the fibula to the tibia on the right by means of a single metallic screw was performed in April 1950. Three months later the patient returned complaining of palsy of the left peroneal nerve and was treated again by internal fixation.

Function of the peroneal nerve was recovered and the patient did well for several months until bone resorption occurred in the area about the screws and fixation was lost; once again she was plagued with dislocations. Numbness over the outer aspect of both legs and over the dorsum of the feet and outer half of the soles was associated with the dislocations and both feet had assumed a position of equinovarus. The patient was again fitted with braces which she wore for a five-year period and then gradually discarded[2].

The patient was first seen by the authors in February 1957 at which time she complained of recurrent dislocations of both fibular heads accompanied by local discomfort. The patellar, ankle, and plantar reflexes were equal and active bilaterally. The Babinski sign was absent. There was neither anaesthesia nor hypaesthesia to pin prick over the lower extremities. The patient was able to perform plantar flexion and to invert and evert both feet with excellent power. There was marked weakness of the tibialis anterior and extensor hallucis longus muscles bilaterally. The examiner was able to displace the proximal portion of the right fibula posteriorly at will. Operation was performed on both legs with removal of the screws and resection of the proximal portion of the fibulae.

Progress of the patient has been followed for fourteen months. She has regained full strength in the affected muscles of the leg and her neurological status continues to be normal. Two months following surgery the patient joined a baseball team and was able to play without pain or disability for the entire season.

COMMENT

The proximal and distal tibiofibular articulations exhibit rather free mobility so that attempts to fix these joints by the use of screws is often followed by bone resorption in the area about the screws or by the screws breaking. In view of this circumstance, and the actual experience with this patient, it would seem to be better to adopt some other form of treatment.

Arthrodesis of the proximal tibiofibular joint was considered, but was discarded on the theoretical grounds that it might prevent the normal outward rotation of the fibula which accompanies dorsiflexion of the foot and so lead to wear and tear of the joint. Excision of the proximal portion of the fibulae was then selected as the simpler form of treatment. This was accomplished with an ample margin to prevent any encroachment upon the common peroneal nerves.

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Recurrent Calcified Leiomyoma of the Pelvis and Gluteal Regions Complicated by Pregnancy

A Case Report

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C. W., a Negro registered nurse, married, twenty-seven years old, was first seen in the Vanderbilt Clinic, New York City, on June 10, 1953. Her chief complaint was of a painful mass in the left buttock with the pain radiating down the left limb. A painful mass had developed in the left buttock following a bruise when the patient was three years old. The mass was removed at that time. At ten and fourteen years she was operated on again for recurrences of a painful mass in the original site. All records of these surgical procedures had been destroyed.

In 1950, at twenty-four, she again noticed recurrence of the tumor in the same location. This mass had grown slowly and had caused no pain until three months prior to admission, when tenderness and pain developed with the pain radiating down the left limb. She was in the tenth week of pregnancy. The rest of her medical history was non-contributory except for caesarean section performed for a term pregnancy two years prior to admission.

Physical examination revealed a tender mass (eight by ten centimeters) in the left buttock in the area of the greater sciatic notch. The left lower extremity showed generalized muscle atrophy. There was considerable quadriceps weakness. There was no sensory loss. Hip motion was slightly limited. Rectal and pelvic examination revealed a firm, tender mass, eight by eight by six centimeters, occupying the left half of the true pelvis, displacing the rectum to the right.

Routine laboratory examination showed that blood count and urinalysis were within normal limits. A Mazzini test, which was negative, was done on three occasions. Erythrocyte sedimentation rate (Westergren) was found to be 32 millimeters after one hour. Blood studies revealed: alkaline phosphatase, 2.9 Bodansky units; serum phosphorus, 3 milligrams per 100 milliliters; serum calcium, 10.4 milligrams per 100 milliliters; and serum uric acid, 3 milligrams per 100 milliliters.

Roentgenograms of the pelvis showed spectacular calcium deposits in the left buttock and pelvis (Figs. 1-A and 1-B). Roentgenogram of the chest was within normal limits. The nature of the calcific masses could not be determined on roentgenographic examination, but a calcifying tumor, or a calcifying hematoma or possibly a localized area of calcinosis was among the conditions suspected.

Because the patient was having considerable pain and in view of her pregnancy, it was decided that the nature of the mass should be determined by adequate biopsy and pathological examination. The patient was admitted to the Presbyterian Hospital on July 20, 1953.

On July 24, 1953, an open biopsy of the mass in the left buttock was done. The tumor appeared well delineated and encased in a thin capsule and was dark red. Many dilated veins covered its surface; it bled easily. It lay directly beneath the glutaeus maximus muscle and appeared to arise, by a broad firm pedicle, from the region of the greater sciatic notch. Total excision was impossible. A wedge shaped specimen (three by seven centimeters) was removed for biopsy. The profuse bleeding which occurred was difficult to stop, but was finally achieved by placing gelfoam between the cut surfaces of the tumor and closing the wound with mattress suture. The wound healed by primary intention and without hematomata.

Microscopic examination of the pathological sections showed a well differentiated, encapsulated tumor of smooth muscle, arranged in whorls and bands with occasional suggestion of palisading. It was highly vascular, many of the vessels being of fair size with definite muscular walls. Patches of calcium were found scattered in the tumor. The pathological diagnosis was leiomyoma, calcified and vascular. A pathologist suggested that the rapid enlargement of the tumor may have been related to the patient's pregnancy.

Members of the obstetrical service felt that the patient should be permitted to reach a full-term pregnancy and then be delivered by caesarean section. A decision was made to postpone definite therapy for the tumor until at least six weeks postpartum. Irradiation

FIG. 1-A

FIG. 1-B

Figs. 1-A and 1-B: Anteroposterior and lateral roentgenograms of pelvis showing extensive calcification throughout the tumor.

therapy was considered inadequate for the tumor and inadvisable during the pregnancy.

The removal of the small wedge of tumor for biopsy oddly enough relieved the patient completely of pain for six months. On December 3, 1953, she was delivered of a normal full-term infant by caesarean section (abdominal) and ligation of the fallopian tubes was performed. A large mass filling three fourths of the true pelvis and attached to the sacrum

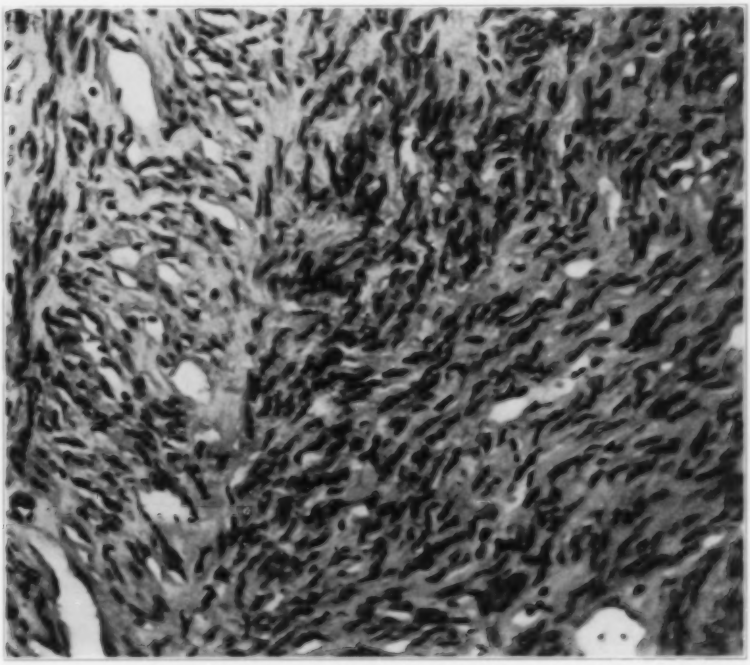

FIG. 2-A

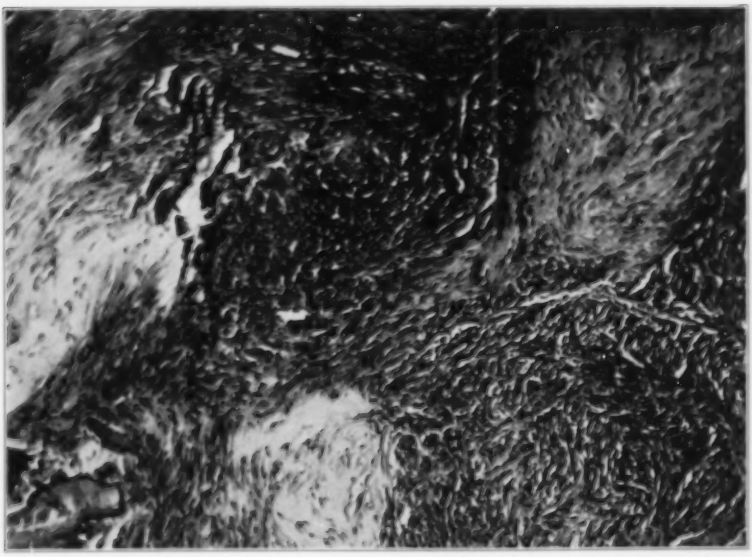

FIG. 2-B

Figs. 2-A and 2-B: Low and high-power photomicrographs of the tumor.

FIG. 3

Roentgenogram of the pelvis and hips three years after removal of the tumor. A small area of residual calcified tissue remains, but this has not changed since the immediate postoperative roentgenograms were made.

and the left pelvic wall was revealed. There was no connection between the tumor and the body of the uterus.

Pain and tenderness in the mass recurred gradually during a period of three months postpartum. The patient was readmitted to the hospital on March 29, 1954, so that definitive treatment might be initiated. Intravenous pyelograms were within normal limits; ureteral catheterization showed no displacement of the ureters. Radiotherapists who were consulted felt that the vascularity of the tumor could not be appreciably reduced by irradiation therapy preparatory to surgery.

It was decided to remove the tumor in two stages; first, the portion involving the pelvis, and, subsequently, the portion involving the buttock.

On April 4, 1954, the intrapelvic portion was approached through an oblique incision in the lower left quadrant. Again, many dilated veins were noted on the surface of the tumor. The arterial streams which were seen in some were eliminated when the hypogastric artery was occluded. Dissection around the tumor was an extremely bloody procedure. Since it was fixed to the sciatic notch by a calcified bridge leading to the buttock portion, dissection of the tumor of the pelvic floor and the hollow of the sacrum had to be blunt and blind. Eventually, uncontrollable rapid bleeding from the many torn veins developed and the patient went into shock. The tumor was then rapidly removed in piecemeal fashion and the operative area packed tightly. This stopped the bleeding. The lost blood was replaced by transfusion and the patient was allowed to regain her physiological balance over a ten-minute period. The calcified bridge in the sciatic notch was then avulsed manually. Again there was massive bleeding from the torn veins which was stopped only after tight packing of the pelvic floor with two five-yard rolls. These packs were left in place and the procedure terminated. A small portion of the tumor had to be left.

Fluid given during the operative procedure was: twenty-four pints of blood, nine pints of plasma expander, and four pints of saline—a total of thirty-seven pints of fluid.

The immediate postoperative course was uneventful and the patient showed no signs of nerve or vessel damage to the lower extremity. Gradual removal of the packs was completed by the tenth postoperative day. On the fourteenth postoperative day a large abscess developed deep in the wound which cleared up following intensive irrigation and the use of antibiotics locally and systemically.

By the sixtieth postoperative day the abdominal wound had closed. Ten days later (June 11, 1954) excision of the mass in the buttock was undertaken. The area was exposed

by reflecting the glutaeus maximus medially through a question-mark incision. A large mass, extending from the greater sciatic notch, and several other masses were encountered. One of these lay under the sciatic nerve, spreading it into a thin sheet three centimeters wide. All visible tumorous tissue was completely excised. Bleeding during this procedure again was brisk but was better controlled. Transfusion of only six pints of blood was needed for replacement of blood lost.

Recovery was uneventful. A postoperative roentgenogram showed almost complete absence of the tumor except for a few remaining fragments in the true pelvis. The wound healed by primary intention. The patient was allowed to walk after two weeks. On June 29, 1954, she was able to stand erect and to walk well; she had no pain. Active extension of the left hip against gravity was good in spite of moderate atrophy of the left glutaeus maximus muscle. She was permitted to leave the hospital.

Pathological examination of sections removed from the intrapelvic and gluteal portions of the tumor showed the same type of leiomyoma as that described in the biopsy specimen.

On May 21, 1957, three years after surgery, a complete examination of the patient showed her to be in excellent health and completely asymptomatic. Physical examination showed no evidence of recurrence of the tumor in the buttock or the pelvis. A roentgenogram of the pelvis showed that the residual calcified tumor seen on the films immediately after surgery has remained entirely unchanged (Fig. 3).

COMMENT

The tumor most probably originated in the blood vessels of the retroperitoneum, the buttock, and the thigh. It must be emphasized that the line of separation between vascular leiomyomata and venous hemangiomata is not clearly defined. This tumor tends to be more like leiomyoma, but one would not be far wrong to call it a venous hemangioma containing muscle and fibrous tissue.

Pathological examination showed no evidence of malignant change in the tumor. There was good reason, because of size and location, to regard this tumor with the respect usually accorded a malignant tumor.

Golden and Stout have reported eight retroperitoneal leiomyomata, benign and malignant. Only one was calcified. It was excised and judged to be benign on microscopic examination. Four years later there was local recurrence and metastases appeared. The patient died ten years after the first appearance of symptoms.

It is impossible to predict the behavior of the small amount of residual tumor in the pelvic floor. Since there has been no change in three postoperative years we hope, that with the loss of blood supply, the tumor has lost its vitality. Should it persist, we hope that this same condition will slow its progress.

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A Goniometer Designed for the Hand*

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In recording the range of motion in the joints of a crippled hand, one should have a simple, compact goniometer. Short arms and one-handed operation are

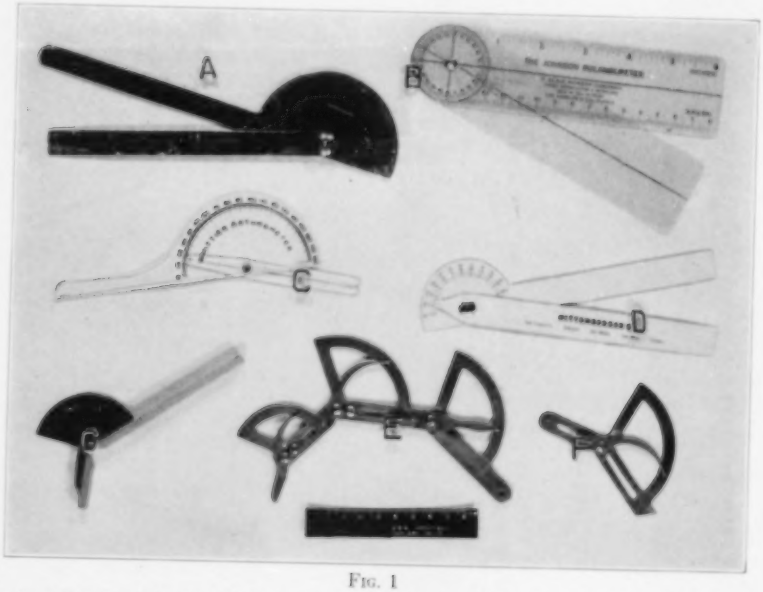

FIG. 1

Goniometers currently used in measuring hands: *A*, standard Robinson; *B*, *C*, and *D*, plastic devices used for advertising by commercial houses; *E*, Pilling compound goniometer; *F*, single section of Pilling goniometer; *G*, Kifa goniometer (European).

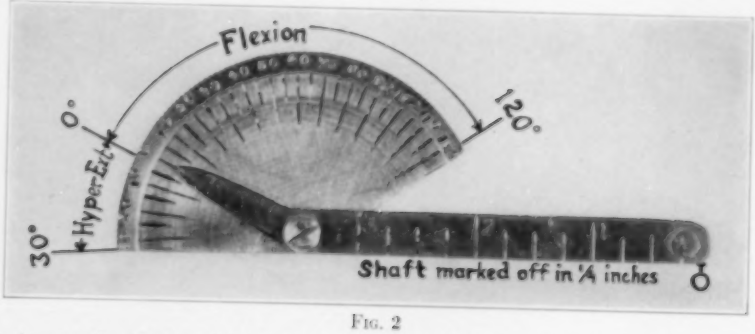

FIG. 2

Goniometer described in this paper. Note that the dial is calibrated both ways from the zero point, and also that the shaft is calibrated away from its distal end.

* The opinions or assertions contained herein are the private ones of the authors and are not to be construed as official or reflecting the views of the Navy or the Naval Service at large.

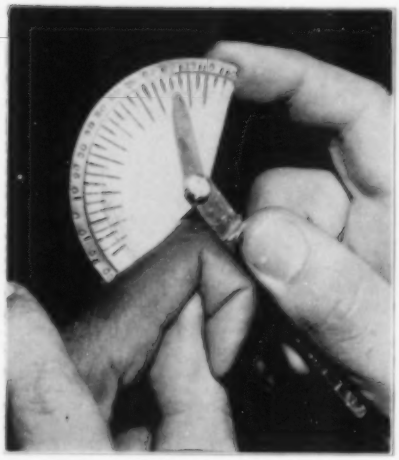

FIG. 3-A

FIG. 3-B

Fig. 3-A: Angular measurement of flexion of the middle joint (92 degrees).
Fig. 3-B: Angular measurement of hyperextension of the middle joint (25 degrees).

FIG. 4-A

FIG. 4-B

Fig. 4-A: Linear measurement of the failure to flex the fingertip into the mid-palmar crease (two and an eighth inches).
Fig. 4-B: Linear measurement of the failure to extend the fingertip into the plane of the metacarpals (one and a quarter inches).

desirable in order that the other hand may be left free to manipulate the patient's fingers. Both the hyperextension and the flexion of a joint should be readily determined in the same motion.

The only American goniometer commercially available, specifically designed for use in the hand, was patented by Pilling in 1918 (Fig. 1). This ingenious machine has three segments intended to measure all finger joints simultaneously; it is adjustable for phalangeal length. There are two objections to it, however: to control its five adjustments requires at least two hands, and it is now real-

ized that in most cases the simultaneous measurement of all joints is inadvisable, the evaluation of each joint individually being of greater use.

The goniometer designed by the authors (Fig. 2) has a double shaft for stability and a knurled edge on the dial for one-finger manipulation. The dial is calibrated on each side, and reads directly from 30 degrees of hyperextension, passing the conspicuous zero point, to 120 degrees of flexion.

On determining the measurement, the double shaft is pinched together, thus seizing the dial and fixing the measurement until read (Figs. 3-A and 3-B).

As an added convenience the shaft has been calibrated in inches on each side to determine how much a digit fails of full flexion or extension (Figs. 4-A and 4-B) and to give the range of motion.

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Anteroposterior Projection of the Carpometacarpal Joint of the Thumb By Radial Shift of the Carpal Tunnel View

BY MICHAEL BURMAN, M.D., NEW YORK, N. Y.

When the central ray of the roentgenographic beam is displaced radially in the carpal tunnel view of the wrist, it passes through the joint between the greater multangular bone and the first metacarpal bone. This joint is seen in anteroposterior projection, distorted by magnification. The base of the metacarpal bone is seen in convex profile and that of the greater multangular bone

FIG. 1-A

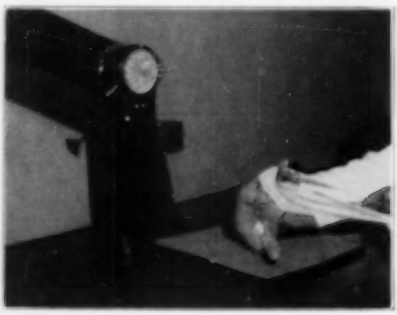

FIG. 1-B

Fig. 1-A: The wrist is hyperextended passively and the abducted thumb placed on the cardboard film holder as shown. The spot focus, marked by a rectangle of adhesive, is a little distal to the carpometacarpal joint of the thumb. The end of the focusing tube overlies the adhesive marker and almost touches it. The tube distance is eighteen inches. Note the angle of the tube which is about 45 degrees.

Fig. 1-B: The focusing tube has been removed and the roentgenogram made.

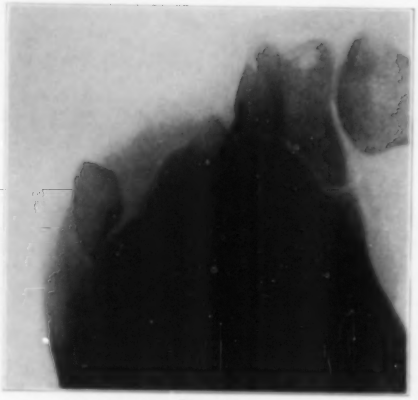

FIG. 2

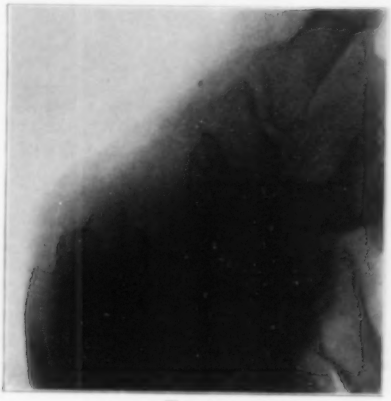

FIG. 3

Fig. 2: The radially shifted carpal tunnel view of a normal wrist and thumb shows the magnified carpometacarpal joint of the thumb whose profile is concavo-convex.

Fig. 3: The greater multangular bone shows an oval exostosis at its volar and ulnar corner just above the tuberosity of the scaphoid bone.

in concave profile, the joint outline being concavoconvex. (Since the carpometacarpal joint of the thumb is a saddle joint, the lateral view must have a convexoconcave profile.)

A true lateral view is difficult and uncertain. This shifted roentgenographic view of the carpometacarpal joint of the thumb is clearer than that of the routine anteroposterior view and may supplement it when dorsiflexion of the wrist is allowed. [1]

1. BURMAN, MICHAEL: Luxation or Subluxation of the Carpometacarpal Joint of the Thumb. J. Internat. Coll. Surgeons, **24**: 45-63, 1955.

Anterior-Angled Plates for High Femoral Osteotomies

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Anterior-angled plates for fixation in subtrochanteric osteotomies during Milch-Batchelor arthroplasties of the hip have been described[1]. Further modifications of the plate were made by Mayer[2]. It is the purpose of this paper to present an additional application of the anterior-angled plates used for fixation during high femoral osteotomies. So far they have been used only in adults; however, there is no objection to smaller models being used in children.

The plates are made with angles of two sizes, 110 degrees and 135 degrees, and in right and left models. They are machined out of one piece of AISI 326 stainless steel or titanium or they are cast in Vitallium (Fig. 1). These predetermined angles, which have been suitable in all cases so far, avoid the necessity of bending the plates to fit the lateral surface of the osteotomized femur. Thus, damage to metal, which might otherwise result in corrosion and weakening of the plate, is avoided. The range of sizes of the four plates was sufficient for the routine internal fixation of McMurray and subtrochanteric osteotomies, used with or without a bone graft in the treatment of non-union of the femoral neck (Fig. 2).

The plate is applied to the anterior surface of the femur with its angle at the point of osteotomy. Two or three coarse-threaded Sherman-type screws hold the upper blade to the greater trochanter from the anterior to the posterior cortex. Three or four screws hold the plate to the upper end of the shaft. The lower blade of the angled Vitallium plate is curved to fit the cortex of the femoral shaft, while

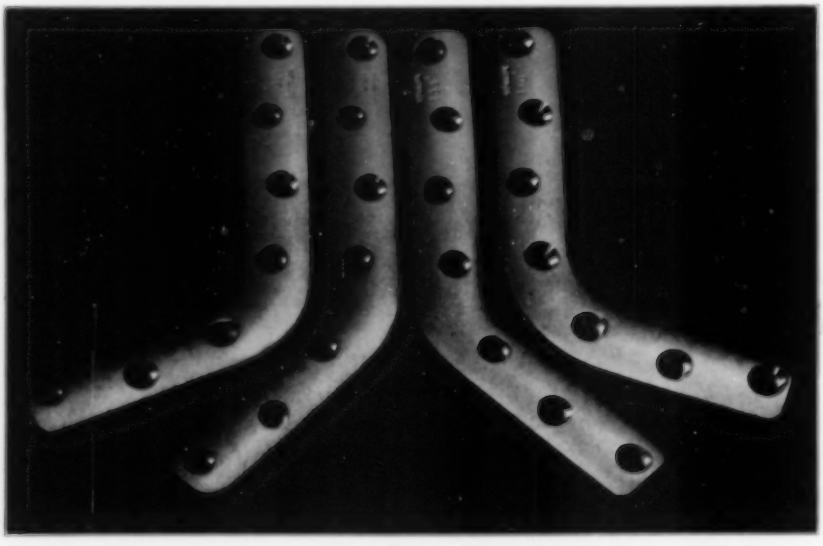

FIG. 1

Anterior view of osteotomy plates, cast in Vitallium, with angles of 110 degrees and 135 degrees.

FIG. 2

Roentgenogram showing fixation at the site of a subtrochanteric osteotomy in a patient with infantile coxa vara.

the upper blade is flat and fits snugly along the anterior surface of the greater trochanter. If this upper blade does not fit snugly enough, it is easy to trim any bone projections with an osteotome, thus allowing good metal-to-bone contact.

The only real disadvantage that was encountered in the first fifteen patients in whom this plate was used was the difficulty in fitting the plate to very high oblique osteotomies, such as the Leadbetter type. In these cases the trochanteric fragment may be too small to accommodate the upper blade of the plate. The 110-degree plate was especially designed for McMurray osteotomies.

Postoperatively, the limb is suspended in split Russell traction or in a Thomas splint with a Pearson kneepiece for six weeks. Recently, traction was not used, and the patient was able to lift the limb off the Thomas splint within a few days. If roentgenograms made in six weeks show adequate callus formation, suspension is removed. Sometimes a further two-week support is required. Non-weight-bearing exercises on the side operated upon are initiated for the next four to six weeks. At this time, weight-bearing on the other limb is allowed. Solid union at the osteotomy site is usually present and full weight-bearing is allowed.

The advantages claimed for this method of internal fixation of high femoral osteotomies are the following:

1. The plate achieves easy and secure fixation of bone fragments, allowing early limb mobilization and avoiding the danger of stiffness, especially in older people, from plaster casts.

2. The plate secures a hold on the greater trochanter from the anterior to the posterior cortex. This is considered better than the hold obtained by spline plates in the cancellous bone of the interior of the trochanter.

3. Preset angles of 110 degrees and 135 degrees for both right and left femora, machined or cast in one piece, not only fit the sites of the most often performed osteotomies, but also prevent damage to the metal by eliminating the necessity to bend the plates.

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A Follow-up Study of the Initial Group of Cases of Skeletal Tuberculosis Treated with Streptomycin, 1946-1948

THE UNITED STATES VETERANS ADMINISTRATION AND ARMED FORCES COOPERATIVE STUDIES OF TUBERCULOSIS

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The therapeutic effect of antimicrobial agents in the therapy of tuberculosis is under continuing evaluation. The efficacy of these agents has been evaluated chiefly in pulmonary tuberculosis; a large amount of valid and significant data has been accumulated as a guide to therapy. The effect of these agents upon extrapulmonary tuberculosis, particularly skeletal lesions, has not yet been as adequately studied. It was felt that a retrospective study of a group of cases of skeletal tuberculosis treated with a single antimicrobial agent for fairly uniform periods and followed for more than five years could provide data of its effect on survival, relapse after treatment, the course of such complications as paravertebral abscess and sinus, and the degree of functional recovery.

The results of such a study become significant by comparison with available data from series reported from the pre-chemotherapy era [1, 3, 4, 5, 6, 8, 10, 11, 12, 13, 14]. A particularly valuable detailed baseline study from this group is furnished by LaFond from a follow-up of 230 patients treated at Glen Lake Sanatorium in the period 1928 through 1946.

MATERIAL AND METHODS

This study presents a follow-up to January 1, 1957, of 187 consecutive patients with skeletal tuberculosis, treated in Veterans Administration hospitals during the period 1946 to 1948, who received short courses of streptomycin alone. This series was presented at the Eighth Streptomycin Conference in November 1949, after a jury review evaluation of therapeutic results as demonstrated by roentgenographic change [16]. No further clinical observations upon the group have since been reported.

All patients in the present study were observed for some period after initial antimicrobial therapy, the minimum being six months. Ninety-five per cent of the group were observed for five years and 70 per cent for eight years. Reports from Veterans Administration hospitals and Regional Offices follow-up examinations, as well as information from the patient and his private physician in many instances, provided the bulk of after-treatment observations. A current listing of all deaths among the entire group was secured from the Veterans Administration Central Office, and the clinical records of all patients who died were reviewed by the author from hospital records, physician's records, and other sources. A large number of hospital clinical records were also reviewed to supplement information on the remainder of the group. Evaluation of roentgenographic change was not a part of this study.

Age and Sex Distribution

Of the group, 70 per cent were between twenty-one and forty years of age at the time of institution of initial streptomycin therapy. The next largest group

(18 per cent) was between fifty-one and sixty years of age. These age distributions represent the selection factors of military service in World War I and World War II, as does the fact that there was only one female in the series. Fifty-six (30 per cent) of the patients were not white.

Distribution of Lesions

The distribution and location of lesions (Table I) is based upon the number of patients and the lesions to which antimicrobial therapy was specifically directed—not the total number of lesions. Sixteen patients (8 per cent) had multiple skeletal lesions, but all other patients had single lesions. Lesions of the spine were present in 60 per cent of the patients in this series, and in 58 per cent of LaFond's patients. In general, the distribution of lesions in both series is closely comparable.

TABLE I

DISTRIBUTION OF LESION TREATED

Location of Weight-Bearing Lesion		Number
Spine		112
Other		
Knee	18	
Hip	12	
Ankle	5	
Foot	4	39
Location of Non-Weight-Bearing Lesions		
Wrist	11	
Shoulder	6	
Ribs	6	
Pubis	5	
Elbow	3	
Other	5	36
Total		187

TABLE II

OTHER TUBERCULOUS LESIONS PRESENT AT THE START OF CHEMOTHERAPY IN 187 CASES OF SKELETAL TUBERCULOSIS

Lesions	Pulmonary	Genito-urinary	Pulmonary and Genito-urinary	Other
Spine	45	3	10	1
Weight-bearing joints	12	2	2	1
Non-weight-bearing locations	24	0	14	1
Totals	81	5	26	3

Chemotherapy

Antimicrobial therapy consisted in streptomycin alone, given in dosage of either one or two grams daily. A few patients received dihydrostreptomycin in 1948. Ten patients in the series received streptomycin in 1946, ninety-seven in 1947, and eighty in 1948. Fifty patients had forty to sixty days of chemotherapy, thirty-two had sixty-one to ninety days, ninety had ninety-one to 120 days, and

only fifteen had more than 120 days of chemotherapy as the initial course of treatment.

Forty-one patients had subsequent treatment with streptomycin during the same period of hospitalization in which they had had the initial treatment. This rarely exceeded 120 days of additional chemotherapy and averaged seventy days. Sixteen patients had up to forty-two days of retreatment, six had forty-two to sixty days, twelve had sixty-one to ninety days, and only seven had more than ninety days of additional treatment with streptomycin during the initial period of hospitalization.

TABLE III

THE EFFECT OF SURGERY AND OTHER FACTORS UPON THE COURSE OF THE PATIENT WITH TUBERCULOUS PARAVERTEBRAL ABSCESS

	Surgery (34) (*No. of Cases*)	No Surgery (33) (*No. of Cases*)
Death		
Tuberculous	3	4
Non-tuberculous	4	1
Reactivation and new lesions	5	10
Working or able to work	23	16
Associated tuberculosis	16 (47%)	20 (60%)
Average age (*years*)	31	33
Spine fusion	26	27

TABLE IV

THE INCIDENCE OF TUBERCULOUS RELAPSE (REACTIVATION AND NEW LESIONS) FOLLOWING STREPTOMYCIN THERAPY

	Spine	Other Skeletal	Pulmonary	Genito-urinary	Other	Total
Reactivation	4	4	20	5	4	37
New lesions	8	7	2	8	5	30
	12	11	22	13	9	67

Associated Tuberculosis

Eighty-one (43 per cent) of the patients in the series had a concomitant diagnosis of pulmonary tuberculosis at the onset of chemotherapy (Table II). An additional twenty-six (13 per cent) had combined pulmonary and genito-urinary tuberculosis, and five (3 per cent) had genito-urinary tuberculosis alone. The incidence of associated pulmonary and genito-urinary lesions, alone or combined, was as high in patients with lesions in non-weight-bearing locations as in those with spine lesions. The high incidence of associated extraskeletal tuberculosis, particularly pulmonary tuberculosis, is a frequent finding in other series [1, 4, 10, 12].

RESULTS

Abscess

Sixty-seven (60 per cent) of the patients with spine lesions had associated paravertebral or psoas abscesses, compared with 71 per cent of LaFond's series. In thirty-four (50 per cent) of the patients with abscess in the present study, the abscess was treated surgically. There were only four instances of recurrence of

abscess associated with vertebral lesions. There was no recurrence in patients in whom the abscess had been treated surgically.

Those who had not been treated surgically had a slightly higher death rate from tuberculosis and had a higher rate of relapse and new lesions; fewer patients were working or able to work (Table III). Both groups were approximately equal in average age. The incidence of associated tuberculosis was definitely greater in the group of patients not treated surgically. The poor results in these patients are probably not primarily the result of failure to drain the abscess, but may reflect the extent of associated tuberculosis and the less favorable risk of the patients as candidates for surgery.

Spine Fusion

Seventy-seven (69 per cent) of the patients with spine lesions had fusion, as compared with 31 per cent in LaFond's series. Arthrodesis of joints or other surgical procedures, exclusive of aspiration, were done in half of the patients with non-vertebral lesions. The incidence of surgery in other than vertebral lesions is quite comparable with that reported by LaFond. In general, the patients in this study were subjected to more surgical procedures in the treatment of skeletal lesions or their complications. The higher incidence of spine fusion in this study probably reflects the effect of improved techniques and the fact that chemotherapy allowed earlier surgery.

Sinuses

Fifty-four (48 per cent) of the patients with vertebral lesions had associated draining sinuses. In half of these patients the sinus tracts were excised or otherwise surgically treated. Sixty-five per cent of the sinuses occurred in patients with paravertebral abscesses, compared with 35 per cent in those patients with tuberculosis of the spine without paravertebral abscess. There was one recurrence in the group of patients treated with surgery and one in the group treated without surgery.

Relapse

The total rate of relapse (reactivations and new lesions) was 35 per cent (Table IV). The majority of relapses occurred within the first five years after initial streptomycin therapy. New tuberculous lesions occurred in thirty patients (16 per cent), fairly equally divided among genito-urinary, vertebral, and other skeletal areas. There were only two new pulmonary lesions (1 per cent), compared with an incidence of 10 per cent in LaFond's series.

The rate of reactivation of all tuberculous lesions following initial streptomycin therapy was 20 per cent, of which more than half (54 per cent) were due to pulmonary tuberculosis. The incidence in LaFond's series was 24 per cent, of which slightly less than half (47 per cent) were pulmonary reactivations. There were only four reactivations (2 per cent) of spine lesions and the same number affecting other skeletal lesions. These were 14 per cent and 18 per cent, respectively, in LaFond's series, suggesting the effect of antimicrobial therapy and the increased incidence of surgery in reducing the reactivation of skeletal lesions in this study.

Comparison with the study by LaFond indicates a high incidence of relapse in both series during the first five years of observation, based upon the life-table method (Chart I). However, the two series are not comparable in this area because of selective factors used in the studies. Relapse in the Glen Lake study by LaFond was defined as "any return to treatment for tuberculosis after the patient had been discharged for more than six months." In the present study any reactivation or new lesion occurring after the initiation of streptomycin therapy was included as a relapse. It is likely that LaFond's series would have shown a much

higher incidence of relapse, had all reactivations and new lesions been included from the beginning of hospital treatment. The series of patients treated with streptomycin does have a lower trend in the incidence of relapse after the five-year observation period (Chart I). However, the comparative rates of reactivation and new lesions noted previously are influenced by the selective factors defined for each series.

Mortality

There were thirty-three deaths (18 per cent) in the series, of which eighteen (55 per cent) were due to tuberculosis and fifteen (45 per cent) to non-tuberculous

TABLE V

THE EFFECT OF THE DURATION OF CHEMOTHERAPY (STREPTOMYCIN ONLY) UPON RELAPSE AND DEATH FROM TUBERCULOSIS
(Spine Lesions Compared with All Other Skeletal Lesions)

Original Treatment	Number	Reactivations and New Lesions (*No.*)	(*Per cent*)	Deaths (*No.*)	(*Per cent*)
Less than 60 days					
Spine lesions	17	10	53	1	10
Other lesions	15	6	40	2	13
61 to 90 days					
Spine lesions	11	2	20	0	0
Other lesions	4	0	0	1	25
91 to 120 days					
Spine lesions	60	18	30	5	8
Other lesions	39	12	30	5	13
*Retreatments**					
Spine lesions	24	8	33	3	12
Other lesions	17	10	59	1	6

*More than one course of streptomycin during initial hospitalization for treatment of skeletal tuberculosis.

TABLE VI

STATUS OF 187 PATIENTS WITH SKELETAL TUBERCULOSIS TEN YEARS AFTER INITIAL THERAPY WITH STREPTOMYCIN

Lesion	Able to Work	Unable to Work	Hospitalized	Dead*
Spine	74	17	6	15
Weight-bearing	20	9	1	9
Non-weight-bearing	21	2	4	9
Totals	115 (74%)	28	11	33 (18%)

*All Causes

causes. Thirteen deaths were due to pulmonary tuberculosis, including three with miliary involvement. Four deaths were due to tuberculous meningitis and one to combined miliary-meningeal involvement. The average age at death was forty-one years, for both tuberculous and non-tuberculous causes. The majority of the tuberculous deaths occurred in the first three years of observation.

Death rates in other series prior to the advent of streptomycin varied from 7 per cent to 28 per cent [5,10,12,13,14], with the rate usually at 25 per cent or more for the series with longer follow-up. The effect of associated tuberculosis, particularly pulmonary tuberculosis, upon mortality is also evident. Nearly 50 per cent of the patients in LaFond's series had succumbed at the end of the first ten-year

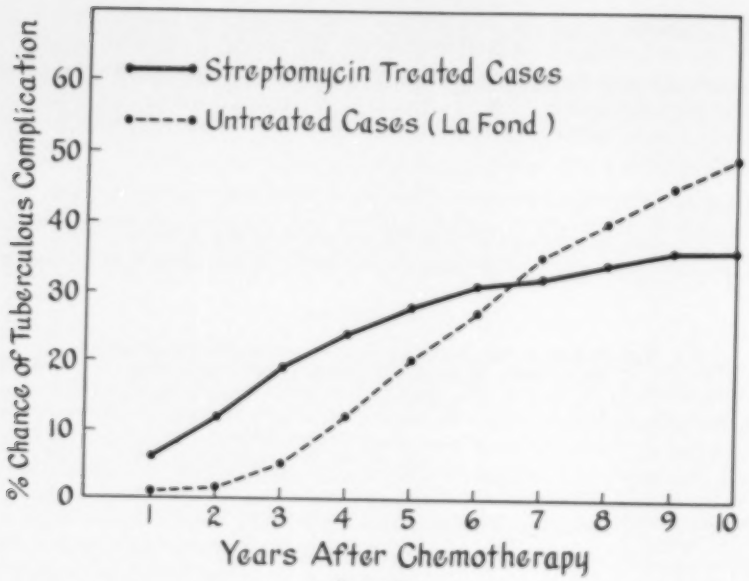

CHART I

The incidence of tuberculous complications in patients with skeletal tuberculosis (life-table method).

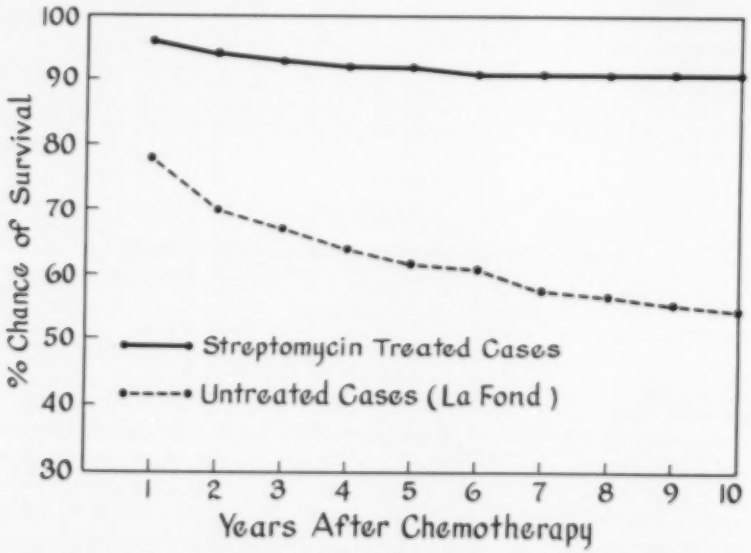

CHART II

Incidence of deaths due to tuberculosis among patients with skeletal tuberculosis (life-table method).

observation period and 81 per cent of all deaths were due to tuberculosis. Chapman reports a mortality reduction of more than 75 per cent in the treatment of skeletal tuberculosis since the introduction of antimicrobial agents.

The chance for survival from tuberculosis in the present study, based upon the life-table method, was 92 per cent at five years and 91 per cent at ten years of observation (Chart II). Analysis of LaFond's data from the Glen Lake Sana-

torium study on the same basis, reveals an expectation for survival from tuberculosis of only 61 per cent at five years and 55 per cent at ten years. The differences between the two series at the five-year and ten-year points of comparison are statistically significant ($p = .001$ at one degree of freedom).

Duration of Chemotherapy and Relapse

The effect of the duration of chemotherapy upon relapse and death from tuberculosis has been analyzed for spine lesions alone and has been compared with that from all other lesions (Table V). In both groups, the patients treated less than sixty days had the highest incidence of tuberculous relapse. The next highest rate of relapse was in the patients in whom retreatment was required. Patients receiving sixty to ninety days of streptomycin had the lowest incidence of relapse, but the total number was small. The effect of less than two months of streptomycin appears definitely inferior to the longer course of treatment. The patients in whom retreatment was required were undoubtedly a less favorable group by virtue of their need for additional chemotherapy. The eighteen deaths from tuberculosis were equally divided among the two groups, with a mortality rate of 8 per cent among the patients with spine lesions and 12 per cent for all other lesions. The effect of chemotherapy upon mortality for the entire series is significant (Chart II), but a comparison of the effect of the duration of treatment would not be valid because of the small number of deaths involved.

The favorable effect of even a short course of chemotherapy is apparent from a further analysis. Ninety-two (49 per cent) of the patients in the series received only one course of streptomycin and had no subsequent relapse. Similarly, twenty-nine patients (15 per cent) who received additional short courses of streptomycin during their initial hospitalization, usually not more than a total of 120 days also had no relapse. These two groups, approximately two thirds (64 per cent) of the entire series, who received an initial single course of treatment or multiple short courses of treatment with streptomycin had no subsequent clinical relapse, nor did any die of tuberculosis. The effect of subsequent treatment for relapse after initial hospitalization employing longer courses and combinations of antimicrobial agents has undoubtedly influenced the over-all results, particularly in reducing mortality. However, it would appear that streptomycin alone, even in very short courses of treatment by current standards, has had a significant effect.

Functional Result

One hundred and fifteen (74 per cent) of the living patients in the present study were working or able to work at the time of last observation (Table VI); twenty-eight were reported as unable to work, and eleven were hospitalized. Good functional results in tuberculosis of the spine and other skeletal lesions were reported in the prechemotherapy era by Cleveland (56 per cent) and LaFond (67 per cent). Meyerding reported good functional results in 64 per cent of patients with spine lesions only and Harris reported good functional results in 72 per cent.

Reports of other series of skeletal tuberculosis treated with chemotherapy, utilizing combinations of agents and longer courses of treatment confirm the effect of chemotherapy upon the reduction of mortality and relapse [2,3,4,7,9,15,17]. However, the effect of rest, supportive therapy, and good surgical principles upon functional recovery is still basic to the treatment of the skeletal lesion.

SUMMARY

The effect of antimicrobial therapy in this series of patients reflects itself in a lowered rate of tuberculous relapse, a lower death rate from tuberculosis, a greater chance for survival, and a high rate of functional recovery and return to productive activity. Streptomycin alone, given for more than sixty days, appears to have had a significant effect in reducing the relapse rate of all tuberculous

lesions. Sixty-four per cent of the entire group of patients who received a single initial or multiple short courses of treatment with streptomycin for 120 days or less had no subsequent relapse and did not die from tuberculosis. Based upon these findings and reports from other series, it is to be expected that adjunct treatment for skeletal tuberculosis with longer courses of antimicrobial therapy and combinations of such agents should demonstrate a further improvement in the rates of relapse and mortality from tuberculosis, in clinical response, and in an earlier and increased rate of return to productive activity for the patient.

NOTE: The author wishes to thank the various Veterans Administration hospitals and Regional Offices for their excellent cooperation in furnishing information on the patients in the study, particularly those at Chicago, Cleveland, Long Beach and Los Angeles, California, Oteen, North Carolina, Milwaukee, Minneapolis, Philadelphia, St. Louis, and San Francisco, and Mrs. Eileen Dahlberg, Chemotherapy Research Secretary, Veterans Administration Hospital, Minneapolis, Minnesota, for her invaluable aid in securing and compiling data for this study.

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A Review and Analysis of 11,000 Fractures Seen in a Private Practice of Orthopaedic Surgery 1937-1956*

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Access to statistical data concerning a large series of cases in a practice of orthopaedic surgery was recently achieved by means of the diagnostic punch-card file previously described[2]. The next step was to examine the data. Clinical impressions concerning a series of cases can be tested only by the examination of related statistical data, and it is obvious that neither the results nor the value of such examination can be anticipated. The figures simply have to be examined.

This paper presents statistical data of fractures from the experience of the group of orthopaedic surgeons in the private practice of orthopaedic surgery from 1937 to 1956. The practice is located in a city in the southwestern part of the United States and derives from a basic population which has grown from approximately 100,000 in 1940 to more than 200,000 in 1955. Cotton, cattle, a strategic location, and a favorable climate are the bases of the city's varied economy which also includes important oil refining, natural gas, metallic ore, steel, railroad, and manufacturing industries.

The experiences reported upon comprise a total of 11,711 fractures treated in this practice from 1937 to 1956. Of these, 943 were old cases; those of non-union, malunion, or union with deformity or disability sufficient to cause the patient to seek orthopaedic consultation. The remaining 10,768 fractures were fresh or acute fractures. The old fractures were a special group and were so reported (Table V). The 10,768 fresh fractures are listed in Table I according to anatomical site and nature of the fracture, closed or open.

Our experience with fractures derives from a total case load of more than 34,000 patients. The proportion then of fresh fractures in the 1937 to 1956 period is approximately one third (actually 31 per cent, 10,768/34,000) of the total. All compilations in this paper were rounded off to the closest integral number. In Table I, the over-all time period was divided into three separate periods: 1937 through 1945, 1946 through 1950, and 1951 through 1955. During the first period the practice was discontinuous because of World War II. Since then, however, the practice has been continuous and is divided into the five-year periods for comparison. A comparison of the relative frequency of fresh fractures to total cases by time period reveals that no statistically significant change occurred; the proportion is approximately one third in each of the three time periods.

Comparison by anatomical area is made possible by grouping separate fractures into three broad anatomical regions: fractures of the spine and trunk, fractures of the upper limb, and fractures of the lower limb. Reference to Table I reveals that fractures of the upper limb occurred most often, 5,025 times, a relative frequency of 47 per cent (5,025/10,768). Fractures of the lower limb were next, a total of 4,120, a relative frequency of 38 per cent, (4,120/10,768). Fractures of the spine and trunk were third in frequency of occurrence, a total of 1,623, a relative frequency of 15 per cent (1,623/10,768).

*Presented as a Scientific Exhibit at the Annual Meeting of The American Academy of Orthopaedic Surgeons, New York, N. Y., February 1 through 6, 1958.

TABLE I

FRESH FRACTURES ACCORDING TO ANATOMICAL SITE, TYPE (CLOSED OR OPEN) AND YEAR *

	1937–1945			1946–1950			1951–1955			
	C	O	T	C	O	T	C	O	T	GT
Fracture of spine and trunk										
Vertebral column without cord lesion	67	0	67	247	0	247	422	0	422	736
Vertebral column with cord lesion	11	0	11	19	0	19	23	0	23	53
Rib (s)	54	0	54	153	0	153	222	0	222	429
Sternum	2	0	2	7	0	7	11	0	11	20
Pelvis	22	0	22	79	0	79	133	0	133	234
Multiple, of trunk	18	2	20	52	2	54	74	3	77	151
Sub-total										1623
Fracture of upper limb										
Clavicle	58	0	58	218	0	218	310	0	310	586
Scapula	2	0	2	26	0	26	33	0	33	61
Humerus, head and neck	34	0	34	88	1	89	125	0	125	248
Humerus, shaft	15	3	18	46	1	47	95	6	101	166
Humerus, distal end	71	0	71	169	5	174	237	4	241	486
Colles	93	2	95	157	1	158	194	1	195	448
Reversed Colles or Smith	5	0	5	7	0	7	11	0	11	23
Radius alone	73	0	73	212	3	215	391	3	394	682
Ulna alone	27	2	29	60	2	62	97	4	101	192
Both bones forearm (not Colles or Smith)	79	4	83	216	11	227	331	12	343	653
Carpal bone(s)	11	0	11	102	0	102	108	1	109	222
Metacarpal bone(s)	38	0	38	129	5	134	214	9	223	395
One or more phalanges	45	7	52	213	30	243	325	57	382	677
Multiple, of hand bones	3	1	4	12	2	14	13	3	16	34
Multiple, of upper limb	5	1	6	40	4	44	49	2	51	101
Multiple (both upper limbs) (upper limb with trunk)	6	0	6	22	0	22	22	1	23	51
Sub-total										5025
Fracture of lower limb										
Femur, neck	70	0	70	201	1	202	352	0	352	624
Femur, shaft	36	4	40	72	7	79	116	1	117	236
Femur, distal end	7	1	8	20	3	23	23	2	25	56
Patella	16	1	17	46	1	47	104	5	109	173
Both bones, leg	25	8	33	62	11	73	104	19	123	229
Tibia alone	40	2	42	148	8	156	242	14	256	454
Fibula alone	5	0	5	41	0	41	69	2	71	117
Ankle, malleolus (i)	69	8	77	311	7	318	424	8	432	827
Tarsal bone(s)	23	0	23	135	1	136	171	1	172	331
Metatarsal(s)	26	0	26	141	5	146	210	3	213	385
One or more phalanges	34	0	34	144	11	155	209	14	223	412
Multiple, lower limb	5	1	6	40	13	53	49	9	58	117
Multiple (both lower limbs) (lower with upper limb, or with trunk)	21	0	21	45	13	58	74	6	80	159
Sub-total										4120
Totals	1116	47	1163	3680	148	3828	5587	190	5777	10768

* C = closed fracture; O = open fracture; T = total; and GT = grand total

Table II presents the separate fractures in order of the relative frequency of occurrence. A study of this table reveals that fractures of the ankle (one or both malleoli) occurred most often, 8 per cent relative frequency (827/10,768). Fractures of the back (spinal column without spinal-cord injury) were second with a 7 per cent relative frequency (736/10,768). Fractures of the forearm, fractures of the fingers, and fractures of the hip with approximately the same totals, are next with relative frequencies of 6 per cent. Fractures of the clavicle are next (5 per cent relative frequency). Fractures of the elbow, fractures of both bones of the leg and Colles' fracture follow with closely similar totals and relative frequen-

TABLE II

FRESH FRACTURES ACCORDING TO RELATIVE FREQUENCY OF OCCURRENCE *

Fracture	T	GT	RF (*Per cent*)
Ankle, malleolus(i)	827	10768	8
Vertebral column without cord lesion	736		7
Radius alone	682		6
One or more phalanges, hand	677		6
Both bones forearm (not Colles or Smith)	653		6
Femur (neck)	624		6
Clavicle	586		5
Humerus, distal end	486		4
Tibia alone	454		4
Colles	448		4
Rib(s)	429		4
One or more phalanges, foot	412		4
Metacarpal bone(s)	395		4
Metatarsal(s)	385		3
Tarsal bone(s)	331		3
Humerus, head and neck	248		2
Femur, shaft	236		2
Pelvis	234		2
Both bones, leg	229		2
Carpal bone(s)	222		2
Ulna alone	192		2
Patella	173		1
Humerus, shaft	166		1
Multiple (both lower limbs) (lower limb with upper limb, or with trunk)	159		or
Multiple, of trunk	151		less
Fibula alone	117		
Multiple, lower limb	117		
Multiple, upper limb	101		
Scapula	61		
Femur, distal end	56		
Vertebral column with cord lesion	53		
Multiple (both upper limbs) (upper limbs with trunk)	51		
Multiple of hand bones	34		
Reversed Colles or Smith	23		
Sternum	20		
Total	10768		100

* T = Total of specific fracture; GT = grand total all fractures; and RF = relative frequency of specific fracture.

cies of 4 per cent. Smith's or reversed Colles' fractures, fractures of the distal end of the femur, and fractures of the scapula were relatively infrequent (less than 1 per cent). The relative frequency of multiple fractures (of trunk and either upper or lower extremity) was also low, in no instance more than 2 per cent. Fracture of the sterum occurred least frequently.

The relative frequency of occurrence of the separate fractures (Table II) differs somewhat from that reported by others [1, 4, 5]. This difference is perhaps partially explained by the nature of the practice. In a large institutional practice, combining both out-patient clinic and private patients, it is possible that fractures of the clavicle and Colles' fractures would be seen more often. The fact that the frequency with which Colles' fractures were seen in this practice in the 1937 to 1945 period was twice that of the 1951 to 1955 period (8 per cent and 3 per cent, respectively) is of interest (Table I). Are more of these fractures being treated by the general practitioner? Are fewer of these fractures occurring? A comparison of the rest of the most commonly seen fractures in this practice according to time period shows, over the years, no statistically significant changes in the relative frequency.

TABLE III

FREQUENCY OF FRESH OPEN FRACTURES ACCORDING TO ANATOMICAL SITE *

	T	O	O (*Per cent*)
Fracture of spine and trunk			
Vertebral column without cord lesion	736	0	0
Vertebral column with cord lesion	53	0	0
Rib(s)	429	0	0
Sternum	20	0	0
Pelvis	234	0	0
Multiple, of trunk	151	7	5
Sub-totals	1623	7	.4 of 1
Fracture of upper limb			
Clavicle	586	0	0
Scapula	61	0	0
Humerus, head and neck	248	1	1
Humerus, shaft	166	10	6
Humerus, distal end	486	9	2
Colles	448	4	1
Reversed Colles or Smith	23	0	0
Radius alone	682	6	1
Ulna alone	192	8	4
Both bones forearm (not Colles or Smith)	653	27	4
Carpal bone(s)	222	1	1
Metacarpal bone(s)	395	14	3
One or more phalanges	677	94	14
Multiple, of hand bones	34	6	18
Multiple, of upper limb	101	7	7
Multiple (both upper limbs) (upper limb with trunk)	51	1	2
Sub-totals	5025	188	3
Fracture of lower limb			
Femur, neck	624	1	1
Femur, shaft	236	12	5
Femur, distal end	56	6	11
Patella	173	7	4
Both bones, leg	229	38	17
Tibia alone	454	24	5
Fibula alone	117	2	2
Ankle, malleolus(i)	827	23	3
Tarsal bone(s)	331	2	1
Metatarsal(s)	385	8	2
One or more phalanges	412	25	6
Multiple, lower limb	117	23	20
Multiple (both lower limbs) (lower limb with upper limb, or with trunk)	159	19	12
Sub-totals	4120	190	4
Totals	10768	385	4

* T = Total fractures; O = Open fractures.

A note of explanation is necessary concerning what appears to be an unusually high incidence of fracture of the tibia alone. These fractures have not been separated into upper, middle, and lower thirds of the shaft so that the group is weighted by the inclusion of all plateau fractures of the tibia. In addition many of these fractures appeared in children, one to ten years old, and were spiral fractures with the fibula remaining intact. Also included are many fractures of the distal tibial epiphysis which was considered part of the tibial shaft rather than part of the malleolus and which was fractured without a concurrent fracture of the fibula. In addition we included with these fractures of the tibia alone a group of cases (about 10 per cent of the total) in which the physician's diagnosis was fracture of the tibia and in which no clinical or roentgenographical reports as to whether the fibula was also fractured were given. This represents a doubtful

TABLE IV

NUMBER OF CASES OF FRESH FRACTURES REQUIRING OPEN OPERATION BY YEAR AND SITE

	1937–1945 (*No. of Cases*)	1946–1950 (*No. of Cases*)	1951–1955 (*No. of Cases*)	Grand Total
Fracture of spine and trunk				
Vertebral column without cord lesion	0	4	8	12
Vertebral column with cord lesion	3	4	4	11
Rib(s)	1	1	0	2
Sternum	0	0	0	0
Pelvis	0	5	6	11
Multiple, of trunk	3	12	14	29
Sub-totals	7	26	32	65
Fracture of upper limb				
Clavicle	1	6	27	34
Scapula	0	0	1	1
Humerus, head and neck	1	7	12	20
Humerus, shaft	4	5	21	30
Humerus, distal end	6	31	61	98
Colles	5	7	9	21
Reversed Colles or Smith	1	0	0	1
Radius alone	4	19	42	65
Ulna alone	6	11	20	37
Both bones forearm (not Colles or Smith)	5	31	51	87
Carpal bone (s)	0	5	8	13
Metacarpal bone (s)	3	21	37	61
One or more phalanges	7	33	80	120
Multiple, of hand bones	2	5	4	11
Multiple, of upper limb	2	9	20	31
Multiple (both upper limbs) (upper limb with trunk)	0	1	4	5
Sub-totals	48	191	397	635
Fracture of lower limb				
Femur, neck	33	146	258	437
Femur, shaft	11	33	61	105
Femur, distal end	4	6	9	19
Patella	6	18	35	59
Both bones, leg	15	29	60	104
Tibia alone	7	33	71	111
Fibula alone	0	0	6	6
Ankle, malleolus (i)	10	65	97	172
Tarsal bone (s)	1	8	30	39
Metatarsal (s)	0	9	18	27
One or more phalanges	0	13	17	30
Multiple, lower limb	3	28	22	53
Multiple (both lower limbs) (lower limb with upper limb, or with trunk)	8	22	32	62
Sub-totals	98	410	716	1224
Totals	152	627	1145	1924

group, but they were tabulated as diagnosed; this explanatory note is offered to obviate misunderstanding.

An examination of the number of open fractures shows the over-all relative frequency in this series to be 4 per cent. Comparison of this frequency by time periods shows that no significant change occurred. In 1955, the risk of open fracture in fresh fractures was not significantly greater than in 1937.

For many fractures, the frequency of open fracture was zero. These include fractures of the back, of the clavicle, of the head of the humerus, and of the hip. The frequency of open fracture according to anatomical site is listed in Table III. It is apparent that this complication occurred with greatest frequency in those patients with multiple fractures (more than one bone of an extremity, or multiple extremities). The single bone fracture most frequently compounded was that

TABLE V

OLD FRACTURES ACCORDING TO ANATOMICAL SITE AND YEAR

	1937 through 1945	1946 through 1950	1951 through 1955	Grand Total
Fracture of spine and trunk				
Vertebral column without cord lesion	17	59	58	134
Vertebral column with cord lesion	1	2	0	3
Rib (s)	2	5	4	11
Sternum	0	0	0	0
Pelvis	1	11	9	21
Multiple, of trunk	3	8	6	17
Fracture of upper limb				
Clavicle	6	12	10	28
Scapula	2	3	1	6
Humerus, head and neck	1	8	3	12
Humerus, shaft	5	5	7	17
Humerus, distal end	12	31	11	54
Colles	15	15	21	51
Reversed Colles or Smith	0	0	0	0
Radius alone	4	12	10	26
Ulna alone	1	11	6	18
Both bones forearm (not Colles or Smith)	10	22	20	52
Carpal bone (s)	1	11	13	25
Metacarpal bone (s)	2	9	5	16
One or more phalanges	3	21	21	45
Multiple, of hand bones	2	3	1	6
Multiple of upper limb	0	3	3	6
Multiple (both upper limbs) (upper limb with trunk)	0	0	0	0
Fracture of lower limb				
Femur, neck	9	28	23	60
Femur, shaft	9	20	15	44
Femur, distal end	3	4	4	11
Patella	2	8	8	18
Both bones, leg	6	12	6	24
Tibia alone	12	30	21	63
Fibula alone	0	4	6	10
Ankle, malleolus (i)	16	30	27	73
Tarsal bone (s)	8	13	8	29
Metatarsal (s)	0	11	7	18
One or more phalanges	0	3	6	9
Multiple, lower limb	1	9	4	14
Multiple (both lower limbs) (lower limb with upper limb or with trunk)	2	12	8	22
Totals	156	435	352	943

of the distal end of the femur (11 per cent relative frequency). Although the total of these fractures is only fifty-six, 11 per cent of these were open fractures. The relative frequency of open fracture in fractures of the lower extremities was slightly greater than that in fractures of the upper extremities, 4 per cent for the lower extremities (total fractures 4,120) and 3 per cent for the upper extremities (total fractures 5,025). The relative frequency of open fracture in fractures of the spine and trunk is only .4 of 1 per cent indicating that the risk of open fracture here is considerably less than in the extremities.

The over-all incidence of open operation was 18 per cent. A comparison of the operative incidence according to the three time periods shows a small but constant increase in the number of patients treated by open procedures. From 1937 through 1945 the operative incidence was 14 per cent, from 1946 through 1950 it was 16 per cent, and for the five-year period from 1951 through 1955, 20 per cent. This increase is undoubtedly related to advances in surgical and anaesthetic technique, in methods of internal fixation of fractures, and to the lessening

risk of operative infections since the advent of the antibiotics. This is especially evident in hip fractures. In the time period from 1937 through 1945, there were seventy patients of whom thirty-three were treated operatively, an operative incidence of 47 per cent. In the five-year period, 1945 to 1950, there were 202 hip fractures of which 146 were treated operatively, an operative incidence of 73 per cent. From 1951 through 1955 the incidence of fractures of the hip treated operatively was also 73 per cent (Table IV).

The operative deaths were reviewed for the five-year period from 1951 through 1955. There was a total of twenty-four operative deaths for the entire five years; an over-all operative mortality rate of less than 2 per cent. The operative mortality rate per year (number of operative deaths compared with the number of patients operated upon) is 2 per cent. The operative deaths occurred preponderantly among the aged with fractures of the hip. There were, however, two postoperative deaths in young individuals. One of these died from an overwhelming peritonitis subsequent to rupture of the jejunum and the other from rupture of a kidney. The ruptures occurred simultaneously with fracture—the deaths were not primarily due to the fracture.

There were three deaths from tetanus. Each of these occurred in young patients with open fractures. The over-all incidence of tetanus infection in this series of fresh fractures is .03 of 1 per cent. It is more meaningful however, to report tetanus in terms of its relative frequency among cases in which there is risk of infection. Accordingly, the relative frequency of occurrence of tetanus infection among cases of open fractures (in which there is increased risk of tetanus) in this series is .8 of 1 per cent.

The data concerning the 943 cases of old fractures are given in Table V. It is apparent that the old fracture most likely to bring the patient to orthopaedic attention is one of the back, with or without spinal-cord injury. The second most commonly seen old fracture was that of the ankle (one or both malleoli). The number of fractures comprising the separate groups is too small to warrant detailed statistical analysis. The incidence of operation in the group of old fractures is 17 per cent, essentially the same as that for the fresh fractures, and the group as a whole.

CONCLUSIONS

The upper and lower extremities are more exposed and mobile than the spine and trunk and, therefore, are fractured more often than the less exposed and better protected spine and trunk. The frequency of fracture, both closed and open, is then greater for the extremities than for spine and trunk.

The statistics in this series show that the risk of open fracture is the same in 1955 as it was in 1937 (4 per cent).

More fractures are amenable to successful operative treatment and more such fractures are being treated operatively.

Fractures (new and old) have comprised approximately one third (31 per cent) of the total cases seen in this practice of orthopaedic surgery and this proportion has remained the same from 1937 to 1956.

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The Boston Orthopedic Institution

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Orthopaedic surgery made its first formal appearance in America when an orthopaedic hospital was opened in Boston in 1838. It was called the Boston Orthopedic (or Orthopedique) Institution, and its founder was Dr. John Ball Brown. Born in 1784, the son of a doctor in Wilmington, Massachusetts, Brown was a graduate of Harvard Medical School (class of 1813). After preceptorship training, he began practice in Boston and in 1815 was appointed surgeon to the Boston Alms House, then the only hospital in the City and State. When the Massachusetts General Hospital was organized, he was appointed associate surgeon and later became consulting surgeon. His medical writings before 1837 contain no evidence of an interest in orthopaedics, and consist of a few case reports and some observations on veterinary surgery. At the age of fifty-four, he became interested in orthopaedics for a personal reason which he expressed in a letter to his father-in-law, Dr. John C. Warren, written in 1837 and published in 1838[1].

"Having lost my eldest son (as you well know) by inflammation of the great spinal cord, and having now my second son confined to his bed by a lateral curvature of the spine, my attention has been forcibly drawn to the study and treatment of spinal diseases generally, and to the correction of other deformities of the human body, such as distortion of the limbs, club feet, etc., etc."

The Boston Orthopedic Institution was first advertised as an Infirmary at 65 Belknap Street (now lower Joy Street)[2]. In an announcement[3], *The Boston Medical and Surgical Journal* stated:

"An institution is now in successful operation, in Boston, for the cure of spinal distortions, club-feet, etc., which has received the appropriate appellation of *Orthopedique Infirmary*. *Orthus* [sic] in Greek, means right, and *pais* child, and which are made use of in French to denote that branch of surgery which has for its object the prevention and cure of deformities in children. There is no word in the English language which has the same signification. This infirmary is conducted by John B. Brown, M.D., at No. 65 Belknap Street. By looking at the prospectus it will be noticed that most of the seniors of the profession in Boston, approve of the plan of treatment, and have kindly offered their gratuitous advice in all difficult cases.

"Under these favorable auspices, there is every reason for believing that the infirmary will prove a useful institution, that it will be judiciously and scientifically managed. In Paris, the Orthopedique Institution has been appreciated by the benevolent, there being a large capital invested in apparatus adapted to the various distortions and deformities of the body—particularly in children and young persons of both sexes. Dr. Brown has recently received a minute report from the two surgeons who control it, which presents a detailed account of the principles and modes of treatment.

"Spinal affections are continually increasing amongst us, as an accompaniment of civilization, and it is important, therefore, that the best mode of correcting and preventing them, should be based upon true anatomical and physiological principles. Until within a few years, comparatively, these complaints, even in Europe, were left to the management of quacks and machine-makers; and much unnecessary suffering and derangement of health has been the unfortunate result.

"Much has been said, of late, of the effects produced on the general condition of the body by compressing the whole trunk in such a manner as to impede the functions of the vital organs. A mode of practice is at this moment in vogue of casing up the patient in a metallic corslet, which is not justified by any discoveries in anatomy. The frame work of man is constructed of material altogether too delicate for enduring the violence inflicted by processes so unphilosophical. We view Dr. Brown's plan of operations for restoring distorted limbs and spinal curvatures, as unexceptionable, because they are sustained by the acknowledged principles of anatomy and physiology. To long professional experience, this gentleman unites a mechanical ingenuity and skill, without which no success can be expected in this peculiar department of surgery. In view of the great and good object he proposes, we cordially wish the infirmary success, and freely express a hope that the community will appreciate the advantages of having it located in this city—under the direction of one who manifests a determination to exert every power to sustain it with increasing reputation. Although comparatively in its infancy, we are assured that the applicants are numerous, and it is much

to be deplored that many calls are from that class of worthy, industrious poor, who are wholly unable to pay for the necessary apparatus. In spinal distortions, particularly, the success of Dr. Brown is extremely encouraging, and will have a tendency to prevent patients from going expensive journeys for medical advice which can be obtained at home.

"It occurs to us to make reference to a case of club-feet, in which the bones were strangely twisted out of place and shape, and in which the restoration is now nearly complete. A little girl, three years of age, both of whose feet were turned in (*vari*), together with the loss of lower extremities from birth,—the bones of the legs being so curved that the fibula of each rested on the anterior part of the tibia, after having been six months a subject of the infirmary, could stand in an erect position, balancing herself in a rocking-chair while in motion. Perhaps this was one of the most difficult and unpromising subjects that could have been selected. She was placed under Dr. Brown's care, we understand, by the recommendation of the President of the Massachusetts Medical Society.

"On the whole, we are gratified with the progress which he is making in this benevolently devised institution, which only requires to be extensively known to be upheld by the strong arm of an intelligent community."

The Institution was a "commodious house . . . under the surveillance of an experienced matron" and was cared for by a "respectable widow woman . . . who furnishes board to patients, either at the common table or in their private rooms [4]." Large halls for orthopaedic excercises were available as was much apparatus. A library also was furnished for use without charge. The capacity of the Institution is indicated by a note stating that under care at one time were twenty-nine spinal cases and twenty-eight cases of club-feet or other deformities of the extremities.

In those days of usual, if not invariable, sepsis following surgery, it is notable that tenotomy was developed and performed frequently. One of the first recorded tenotomies in the United States, performed for club-foot, was done in 1839 by Dr. Brown, only two years after the popularization in England of this procedure by Little. Little had had the procedure done on himself in 1836 after a canvas of European centers where the operation had been performed since 1784 but was not yet an accepted procedure. Brown popularized this procedure and performed as many as one hundred and ten tenotomies in two years, most of them for foot deformities, but some for spinal curvatures as well.

At that time, deformities were classified according to their anatomical configuration without regard to the disease process causing them. In a series of three publications [4,5,6] from the Boston Orthopedic Institution, woodcuts show foot deformities which may now be easily classified as due to arthrogryposis, congenital club-foot, or cerebral palsy, and a description is provided of foot deformities probably due to spasticity from hemiplegia, perhaps the result of cerebral hemmorrhage. All these deformities, in Dr. Brown's hands, were treated by tenotomy supplemented by manipulation and holding apparatus. Spinal curvature, whether due to scoliosis, as one illustration suggests, or tuberculosis, then termed spinal irritation, also was treated by tenotomy. In one instance, the trapezius, longissimus dorsi, and sacrolumbalis were the muscle structures divided.

These operations were performed without anaesthesia during the first eight years of the Boston Orthopedic Institution. The last of the three pamphlets which constitute the main documentation of the establishment [6] reveals that for some years ether anaesthesia was being used on patients undergoing tenotomy. This was not surprising since the Institution was a mere two city blocks from the renowned Ether Dome of the Massachusetts General Hospital, where in 1846, the use of ether for anaesthesia was popularized. The pamphlet, dated 1850, also relates the interesting fact that Buckminster Brown, John Brown's second son, after his medical studies at Harvard, went abroad "for the purpose not only of gathering statistical facts of the state of orthopedy in the Old World, but also to form an acquaintance with the first surgeons and their modes of practice and to establish a correspondence with them." This presages in some degree the traveling orthopaedic fellowships of the present day.

In the manner of the times, the pamphlets contain, besides theoretical con-

siderations of the medical aspects of the two main subjects, club-feet and curvature of the spine, a number of cases illustrating excellent results, and testimonials from satisfied patients or parents of patients. A list of twenty-two physicians who endorsed the purposes and practices of the Institution is also furnished, among whom were a group of consulting surgeons. These rendered advice and aid gratuitously when requested and included Dr. John C. Warren, Professor of Anatomy at Harvard, Dr. George Heyward, Professor of Surgery at Harvard, Dr. J. Mason Warren, Dr. S. D. Townsend, and Dr. Winslow Lewis, Jr., all of whom served as surgeons at the Massachusetts General Hospital.

Even prior to his graduation from Harvard Medical School in 1844, Buckminster Brown assisted his father in orthopaedic procedures at the Orthopedic Institution and later established the first orthopaedic ward at the House of the Good Samaritan in 1861. This antedated by two years the opening of the oldest American orthopaedic hospital still in operation—the Hospital for the Ruptured and Crippled (the Hospital for Special Surgery) in New York City. Dr. Buckminster Brown was responsible for the establishment at Harvard of one of the first chairs in orthopaedic surgery in America, the John B. and Buckminster Brown Professorship. A bequest of $40,000 in his will led to the formation of the Department of Orthopaedic Surgery at Harvard in 1893. E. G. Brackett was appointed Professor in 1903 after having been assistant professor during the intervening years. Buckminster Brown during his active practice thus carried forward the medical interests of his father and practically limited his practice to the specialty of orthopaedic surgery.

The active years of the Boston Orthopedic Institution were from 1837 to 1851. During the last five years of its existence, father and son practiced orthopaedics there, but the details of their conduct of the infirmary as depicted in the three pamphlets, are meager. After 1851, no further listing of the Boston Orthopedic Institution is found in the directories of the City.

It has not been possible to discover the circumstances leading to the closing of this unique institution. Because of the changes in the local street names, and the sketchy records of the time, the exact location of the building remains uncertain, as does its fate. We may surmise that in 1851, John Brown, then sixty-seven years old had reason to discontinue his practice. Buckminster, who always limited his practice because of his own spinal disability, did not perpetuate the institution for reasons which cannot be determined.

The short life and obscure death of the Boston Orthopedic Institution thus mark the beginnings of specialization in the practice of orthopaedics in America. Buckminster Brown, whose illness stimulated its formation and who had his first encounters with orthopaedics there, firmly established the precedent by personal example in practice and writing and by perpetuating the tradition in the university, in the hospitals, and in the community.

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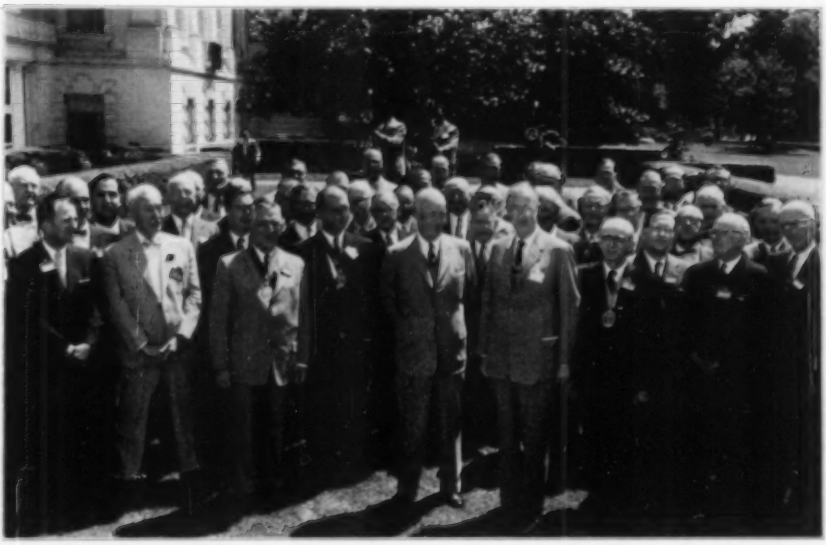
PROCEEDINGS

JOINT MEETING OF THE AMERICAN, THE BRITISH, THE CANADIAN, THE AUSTRALIAN, AND THE SOUTH AFRICAN ORTHOPAEDIC ASSOCIATIONS

After an interval of six years, The Orthopaedic Associations of English-speaking countries, again joined in a combined Annual Meeting. Held May 11 through May 16 in Washington, D. C., the six-day gathering was a memorable one. The orthopaedists of the participating countries then toured various clinics in eastern cities in the United States and Canada, thus continuing the close association to May 28 and beyond. Present were more than 600 orthopaedic surgeons of the participating Associations and guests. Together with their wives, they brought the total attendance to over 1,000.

At mid-morning on Wednesday, May 14, at the White House, President Eisenhower received a deputation of past and present Presidents of the participating Associations and other distinguished members and guests. The warm cordiality of his welcome and the deep sincerity and power of his plea for a deeper understanding and a stronger cooperative spirit among the English-speaking peoples of the world gave voice to the feelings and thoughts which animated all and which prevailed throughout the Meeting.



The Scientific Sessions were held at the Shoreham Hotel, Walter Reed Army Medical Center, and the Armed Forces Institute of Pathology—all of Washington, and at the National Institutes of Health and the National Naval Hospital in nearby Bethesda, Maryland. These sessions, continuing during the five days devoted to them, developed into a happy blend of reports of clinical studies and of basic scientific investigations. Four symposia composed a large part of the program: one on Orthopaedic Problems in Children, one on Arthritis (degenerative, rheumatoid, and osteo-arthritis) held at the National Institute of Health, one on Fractures, and one on Bone Tumors held at the Walter Reed Army Medical Center and the Armed Forces Institute of Pathology.

Audio-visual programs were presented throughout the evening of May 12, throughout the afternoon and evening of May 13 and May 14, and throughout the afternoon of May 15. These featured various new or difficult operative procedures, several analyses of joint and body mechanics, and also special problems in orthopaedic management including that of the juvenile amputee, the spastic child, and the paraplegic.

Far more than all these, in themselves sufficient, was the deep warmth of the feeling of fellowship and of friendliness, and the almost unparalleled opportunity for informal discussions and ready exchange of ideas which inevitably developed deeper understanding of each other and his problems and a firm resolve to continue to work together on a world-wide basis.

Hosts were The American Orthopaedic Association under the Presidency of Dr. George O. Eaton, and The Canadian Orthopaedic Association whose President was Dr. George W. Armstrong. Co-hosts, the warmth and thoughtfulness of whose hospitality seemed almost unbelievable, were the members of the Washington Orthopaedic Club under the Presidency of Dr. John Adams and their gracious, hardworking, efficient, and very well organized wives.

Among the honorary invited guests were, His Excellency Sir Leslie and Lady Munro of The New Zealand Embassy, His Excellency Wentzel C. and Mrs. DuPlessis of The South African Embassy, His Excellency Sir Harold and Lady Caccia of The British Embassy, His Excellency N. A. and Mrs. Robertson of The Canadian Embassy, His Excellency The Hon. Howard and Mrs. Beale of The Australian Embassy, Dr. Frank B. Berry, Assistant Secretary of Defense (Health and Medical), Major General Silas B. Hays, The Surgeon General United States Army, Rear Admiral B. W. Hogan, The Surgeon General United States Navy, and Major General Dan C. Ogle, The Surgeon General United States Air Force.

THE INAUGURAL CEREMONY

The President of The American Orthopaedic Association, Dr. George O. Eaton, wearing the Jewel of Office presented by Her Majesty, Queen Elizabeth, the Queen Mother, at the Joint Meeting in London in 1952, in opening the meeting on the morning of Monday, May 12, extended greetings to the members of the visiting Associations and warmly welcomed all members and guests on behalf of The American Orthopaedic Association. The ceremony which followed was impressive in its simplicity, dignity, and charm.

The Bishop of Washington, the Right Reverend Angus Dun, in giving the invocation, asked that the only rivalry between the surgeons of different countries "be that of excellence in service, keeping mindful that the secret of the care of the patient is to care for the patient" and that in their "stewardship in this ministry to the broken in body, they may minister in some measure to the brokeness of our human family."

MESSAGE FROM THE PRESIDENT OF THE UNITED STATES

Disappointed that he could not be present at the Inaugural Ceremony, President Eisenhower had sent the following message: "Please give my greetings to all attending the Joint Meeting of the English-Speaking Orthopaedic Associations, and a special welcome to our friends from abroad. With skill and high purpose you bring strength to the crippled and afflicted around the world. Coming together from many nations for the purpose of exchanging information and ideas, you provide the basis for further advances in the peaceful progress of mankind. Best wishes for a fine meeting."

The Under Secretary of State for International Organizations, Mr. Francis Wilcox, representing the United States Government, said: "I am greatly honored this morning to have the opportunity to welcome this distinguished international gathering of surgeons and scientists on behalf of the Government of the United States. Webster reminds me that the science of orthopaedics has to do with the correction or prevention of deformities, especially in children. I can think of no higher calling, no greater opportunity to contribute to human betterment. During the current week, you will be participating in meetings and discussion which relate to matters of vital concern to mankind everywhere. Naturally, your primary interest is the alleviation of human suffering, and that alone, of course, is of sufficient importance. However, as one mainly concerned with international organizations, I would like to discuss with you very briefly certain other aspects of international conferences such as the one you are holding now. Meetings of this kind are relatively new. In the past, in fact up to the last century, nations resorted to international conferences only in connection with the larger problems of war and peace. However, with the development of new methods of transportation and communication, the whole community began to use the international conference as a form for the discussion of common problems in the scientific and technological fields. And now the international conference has developed into a standard operating procedure among both governmental and non-governmental organizations, for promoting the well-being of mankind in almost endless areas including the political, social, economic, scientific, medical, and industrial and commercial fields. It has assumed major importance as a means of sharing man's knowledge and expanding his horizons.

The Presidents of the Associations: George W. Armstrong, Canada; Norman Capener, Great Britain; George O. Eaton, United States; J. B. Colquhoun, Australia; and A. J. Helfet, South Africa.

"Your meeting provides an excellent example of this type of conference. Here you will exchange knowledge and new ideas. These exchanges will benefit each of you in the practice of your great profession. Equally important, you will discuss problems common to the profession of your respective countries. I have no doubt that the results of your deliberations will be widely disseminated to your colleagues in many other areas of the world. As a result, peoples everywhere will stand to benefit either directly or indirectly; for if the science of orthopaedics is important today, it promises to be far more important in the years that lie ahead. In your lifetime and mine, if present trends continue, this world of ours will be literally bursting at the seams. Population is increasing at such an explosive rate that it will confront man with a tremendous challenge in providing food and clothing and adequate medical care for our teeming millions. It is estimated that every week now, one and eight-tenths millions of new births occur. Think of it, almost two million new births every week. Every hour that passes welcomes 11,000 new babies into the world. This is indeed a sobering thought, but it does make us appreciate, perhaps a little more, the vast dimensions of the challenge we face in helping solve our health problems on a world-wide basis.

"This international cooperation to alleviate human suffering also can be extended to cooperation between nations on an intergovernmental basis. I refer specifically to the work of the World Health Organization and the specialized agencies of the United Nations. WHO, which is observing now its tenth anniversary, is making, I think, a very substantial contribution to protecting the health and welfare of peoples everywhere. It is, in fact, playing a large part

in the war against debilitating diseases which lower or destroy productivity, which mean poverty and despair to millions of people in many lands. This organization can take credit for a record of solid achievement, achievement which has only been possible through a joint cooperative effort of doctors, scientists, and public health administrators from nations throughout the world. As a result of the lead taken by the WHO and other agencies in the irradication of malaria, millions of people have already been saved from this scourge of mankind. Significant progress is being made in reducing tuberculosis; vast campaigns against yaws have confirmed the practicability of irradicating these diseases and treponematosis. Given continued support for the work of the WHO, there is real hope that many of these destroying diseases can be brought under control and perhaps even routed completely from the face of the earth, if people recognize the importance of international cooperation by both governmental and non-governmental organizations in the field of medicine and health.

"International conferences seldom make front page headlines and their efforts are carried on without a great deal of fanfare, but the results of these efforts are equally, if not more, important, in the long pull, than many of the drama-packed conferences of the diplomats and the statesmen. Through cooperation of this kind, we can make, I think, significant contributions to the creation of those conditions in the world which will formulate the basis for a lasting peace.

"All the political bickerings of ancient Greece are all but forgotten, but the golden age is still remembered for its brilliant and lasting contributions to the arts and the sciences. Today, you are meeting here not only as surgeons and scientists, but envoys of the great English-speaking family of nations which has contributed so much to the advancement of mankind everywhere. I congratulate you and your organizations on the splendid job you are doing, and I wish you every success for the future. I hope very much, Mr. President, that you and all members of the organizations meeting here today enjoy greatly your stay in our city of Washington. Thank you very much."

Dr. Eaton, in welcoming the guests of The American Orthopaedic Association and the members and guests of the visiting Associations, said: "On behalf of The American Orthopaedic Association, it is my great and very pleasant privilege to welcome you to this second Joint Meeting of the Orthopaedic Associations of the English-Speaking World, and the Seventy-First Annual Meeting of The American Orthopaedic Association. The First World War marks the beginning of a close and happy association of British and American orthopaedic surgeons. There is a saying that neither side wins a war, and certainly we know that even the victor must sustain great losses. There are, however, certain characteristic and beneficial by-products of war; the art and science of medicine in general, and orthopaedic surgery in particular, made great progress in each World War. The First World War saw orthopaedic surgery break away from general surgery on both sides of the Atlantic and be recognized in its own right by both military and governmental authority. As soon as the United States entered the war, the British Government officially requested twenty American orthopaedic surgeons to help with the care of British military casualties. And in less than three weeks, twenty orthopaedic surgeons, under the leadership of Dr. Joel Goldthwaite, were on their way to England to work under the direction of the late Sir Robert Jones. 1921 saw this affiliation meeting in joint session in London and in the Second World War, the American Hospital in Britain organized and led by Dr. Philip Wilson, functioned as an orthopaedic unit for over a year before the United States entered the war. In 1948, a combined meeting of the Canadian, British, and American Orthopaedic Associations was held in Quebec under the Presidency of Dr. R. I. Harris, a Canadian President of The American Orthopaedic Association. With members of the three Associations contributing papers and discussions, the exchange of viewpoints was stimulating and valuable. In 1952, the first Joint Meeting of the Orthopaedic Associations of the English-Speaking World was held in London, with South Africa, Australia, and New Zealand represented, as well as Canada, Britain, and the United States. This meeting was characterized by meticulous organization, excellent scientific presentations, and the very cordial hospitality of our British confreres. This Jewel of Office was a gift to The American Orthopaedic Association, presented by Queen Elizabeth, the Queen Mother, and was the gift of the members of the British Orthopaedic Association. Today, we of The American Orthopaedic Association extend a very cordial welcome to our guests and to the members and the guests of the visiting Associations to this meeting, which is arranged in the usual tradition of our Annual Meetings."

Dr. A. R. Shands, Jr., Chairman of the General Committee on Arrangements, before introducing the Presidents of the four visiting Associations, spoke as follows: "It is my privilege at this meeting to welcome with Dr. Eaton the many representatives of other nations who have come to join their American colleagues at the Second Joint Meeting of the six English-Speaking Orthopaedic Associations, and to say for us in the United States what a privilege it is to have with us so many friends from across the sea and from across our northern border with us in Washington on this occasion. Those of us fortunate enough to have attended the Joint Meeting in London in 1952, will never forget the amazing organization and planning, the wonderful hospitality, and the excellent contributions to the Scientific Program and the clinical

hospital sessions, all of which were so ably guided by the mind and hand of Sir Reginald Watson-Jones, whose absence today is a great loss to this meeting. We of the Arrangements Committee, can only hope that our efforts of the past few months may be productive of a meeting which may in some ways be as memorable and successful as that meeting in 1952, which is the best which many of us have ever attended.

"Health, with the practice of medicine represents the most common denominator of all nations. Our field of orthopaedic surgery, the development of which during the past half century we should be justly proud, is a fragment of this whole denominator, but a rather substantial portion, if numbers of patients are to be considered. Health knows no international boundaries, it knows no language barriers, and as Her Majesty, the Queen Mother, so beautifully stated in 1952: 'There should be no frontiers between nations in the common humanity of healing, for there exists but the measure of man's need.' In the Inaugural Ceremony on that same day, Sir Reginald expressed a thought which will bear repeating, 'Few can doubt,' he said, 'that the peace and quietude of the world depends upon the collaboration of English-speaking nations, who bear a heavy responsibility, and none can doubt how great a contribution to their responsibility, and their opportunity, can be made by those of us who are surgeons, scientists, philosophers and friends'. This meeting of surgeons, scientists and friends, and perhaps a few philosophers, though small in number, is another of the many examples of collaboration between English-speaking nations which we hope may some day help to stabilize this turbulent world of ours. No momentous decisions will come from our deliberations this week, but certainly amongst those of us of different nations, will come a deeper and more sympathetic understanding of many of our common scientific and social problems. There will also come a drawing tighter of our bonds of friendship, united by a common language.

"Again, may I say how delighted we are to have so many of our English-speaking colleagues and their ladies here for this meeting, and I do hope that if there is anything the Committee on Arrangements can do to make your stay more pleasant, you will let us know.

"Now it is my pleasure to introduce to you the Presidents of four of the five other English-Speaking Orthopaedic Associations. We are quite disappointed that New Zealand was unable to send a representative and we just had word about a month ago that Mr. Fitzgerald, the President, could not come. First, The Australian Orthopaedic Association, the President, Mr. John Colquhoun."

Mr. Colquhoun said: "Dr. George Eaton, distinguished visitors, ladies and gentlemen. It is a very great privilege to be standing here today in Washington as the President of The Australian Orthopaedic Association. At the meeting in Australia when I was appointed the President, in thanking the Association, I pointed out that it was the first occasion on which a new Australian had been appointed. That may be something that you don't quite understand; but I was the first and only foreign born member to be made President of The Australian Orthopaedic Association. It happens that I was born in Scotland. I am very proud to see one of my teachers, Sir Walter Mercer, a distinguished guest of the American people and the Canadian people here today. I have too, quite an American background, because I was initiated into the mysteries of orthopaedics in Boston, that famous cradle of orthopaedics in America.

"However, be that as it may, it is a very great honor for us to come here, particularly because of the close association of Australian surgeons, general and orthopaedic, with American surgeons in two World Wars. It was particularly pleasant for us to have with us in the Southwest Pacific area, Dr. George Eaton, as a consulting orthopaedic surgeon. And there we met him, and to meet him was to love him, and I think that all of us who did meet him in Australia, still love him and would be very happy if he would come back to see us again. But over and above that, I have also had the pleasure during the war, to command a hospital in Queensland, and my fellow intern from Boston, that well known orthopaedic surgeon, Edwin Cave, was the commanding officer of the American hospital on the plains below. You can imagine the delight we had in meeting each other. Carter Rowe was a member of that team too, and during the time that we were there, knowing how much the Americans loved meetings, we arranged an international orthopaedic meeting in Queensland. Now this was a unique meeting, and Dr. George Eaton will remember it. The late Dr. Ullrich of Baltimore arranged a program in Brisbane on the coast on the first day. On the second day we moved up to Gayndah, the agricultural college which was taken over by the American authorities, and there we had a most pleasant, most stimulating, most profitable day. There was a sort of relaxation by going up to the hills. Eddy Cave said to me, 'I to the hills will lift mine eyes,' and we arranged it for him, we took him up to a place called Toowoomba, and I am sure the members of the American hospital, the Harvard Medical Unit, will always remember Toowoomba and Gayndah and Brisbane with very happy memories. I would like to thank you all, and I would like to tell you of a Danish proverb which I heard many years ago when I was surgeon on the continent: 'Where there is heart-room, there is house-room,' and I can assure you there is a great deal of heart-room throughout Australia for all Americans, and if you do come to us, I hope we will be able to give you house-room too.

"On behalf of The Australian Orthopaedic Association, I would like to thank you sir,

The American Board of Associate Editors with the British Editorial Board and past members of the American Board at dinner Sunday, May 11, 1958.

and your committee, for inviting us to take part in this meeting. I know that we live a long way off, but we felt it was very well worth while to make the journey to come and meet you all and to take part in this meeting. I trust that the meeting will be blessed with success and all happiness that must come in this delightful city. Thank you".

Mr. A. J. Helfet, President of the South African Orthopaedic Association, said: "My colleagues from South Africa and I would like to add our warm thanks to your words of welcome to us today. You have discovered the history and traditions and the happy collaboration which already adorn these meetings of the English-Speaking World, and of which our Association is now privileged to be a part.

"If I might digress for a moment, I have now been in the United States for ten days; I haven't yet reached the stage where I can write a book about the United States, but I am prepared to give you some advice on how to live. It is, that if you have a lot of money, you should eat and sleep in the United States and live in South Africa. But if you haven't much money, you should live in America and eat and sleep in South Africa.

"To many of you, South Africa seems a long way off; an outpost of western medicine at the tip of the dark continent. In its infancy, it was an outpost, and it looked to Europe for its medical strength and sustenance and stimulus. In 1918, the first medical school was established

The American Board of Associates Editors entertained the British Editorial Board at dinner. In this photograph of the head table can be seen R. I. Harris, Norman Capener, Frank Berry, Assistant Secretary of Defense, Health and Medical, Robert W. Johnson, Jr., H. Jackson Burrows, and A. J. Helfet.

in Cape Town, and since then, teaching and practice have developed rapidly. There are now five medical schools, each with a vigorous orthopaedic department. Two years ago, we organized the South African College of Physicians and Surgeons. Sir Walter Mercer was at that time President of the Royal College of Surgeons of Edinburgh and came out to inaugurate the College. At the last meeting of the Council of the College, the principle of a faculty of orthopaedics was accepted. We have, therefore, now reached the happy position where we are able to train our own men to the stage of practice and of reading and of thinking in which they are ready to have their approach to orthopaedics polished and matured by working in Britain and in the United States.

"For the first time, South Africa has had the privilege of electing an Exchange Fellow. For this we are grateful to the American, the British, and the Canadian Orthopaedic Associations. He tells me of the great hospitality and interest and stimulus he has enjoyed. On the post-convention tours, we hope to share some of his experiences.

"In South Africa, our Rhodesian colleagues join with us in the South African Orthopaedic Association, and we are now an active body of over seventy members. Instead of being an outpost, we are, in cooperation with our National Council for the Care of Cripples, impelling the advance of orthopaedics up the broad continent of Africa. An orthopaedic surgeon already practices in Umtali, and others visit the Copper Belt, some two thousand miles north of Cape Town. Now, as Dr. Shands pointed out, orthopaedics, as much as any other branch of medicine,

has demonstrated that it knows no frontiers, either economical or geographical. In the English-speaking family of Orthopaedic Associations, even the curtains (iron, bamboo or silken) cast no shadow. Mr. President, may I use this opportunity to invite you and any members of this combined meeting to join in the clinical discussions at our Annual Meetings. We hold them in our spring, which is your fall or autumn. Dr. Boyd and Dr. Rex Diveley last night showed you some of the environment. Only if you visit us will we be able to reciprocate these pleasing clinical sessions and scenic occasions. Thank you."

Dr. Armstrong, President of The Canadian Orthopaedic Association, said: "Mr. President, members of The American Orthopaedic Association and guests. On behalf of my fellow members of The Canadian Orthopaedic Association, I wish to thank you most sincerely for your kind and gracious welcome. At the same time, I should like to assure you of our genuine pleasure in being here, not only because of the excellent Scientific Program which has been arranged, but also because of the opportunities of strengthening old friendships and forming new ones. This is the first occasion on which The Canadian Orthopaedic Association has met as a body in your country.

"Before founding the Canadian Association ten years ago, your Association and its offspring, The American Academy of Orthopaedic Surgeons, constituted the lifeline of orthopaedic surgery for Canadian surgeons. In saying this, I am not unmindful of the fact that some of our colleagues have pursued postgraduate studies in the British Isles and on the continent, but it is obvious that our proximity to the United States has made it possible for large numbers of us to come here frequently in contrast to the few who have found it possible to go farther afield. Each year we have drunk deeply at your fountains of knowledge and you have extended to us at all times the greatest cordiality and friendship. This is the kind of debt which according to the law of life can be discharged not by repaying the benefactor, but by passing it on. To express our gratitude for all the benefits which we have received through the years, both in scientific knowledge and human friendship, I can do no better than to use the words of the greatest master of the English language, William Shakespeare, 'I can no other answer make but thanks, and thanks and ever thanks.'

"In conclusion, I have the honor and privilege, Mr. President, Ladies and Gentlemen, of bringing to you a personal message from the Right Honorable John Diefenbaker, Prime Minister of Canada, dated April the 29th.

" 'Dear Dr. Armstrong: I was interested to learn from your recent letter that The Canadian Orthopaedic Association, in conjunction with The British Orthopaedic Association and representatives from the Commonwealth countries, will meet this year in Washington, D. C., from May 11th to the 16th as guests of The American Orthopaedic Association. I should be most grateful if you would extend on my behalf to all of those attending the meeting, warmest greetings from Canada. The Canadian Government and people appreciate the important product which our orthopaedic surgeons contribute to the nation's health. The international aspect of the meeting this year will provide an unusual opportunity for all to examine and compare new discoveries and techniques and to draw on the experiences of our friends in many lands. I have much pleasure in sending best wishes for a profitable and fruitful meeting.' "

Dr Shands: Now the anchor man on this team of four Presidents is Mr. Norman Capener, President of The British Orthopaedic Association. Mr. Capener.

Mr. Capener: "I speak this morning not only for the relatively few of us who are privileged to be here as members of the British Orthopaedic Association but also for those we have left behind and who will be thinking of us with envy. With us also they will be full of gratitude for the honour that you have done our Association, for the warmth of your invitation to come here and for the truly wonderful hospitality and overwhelming kindness that we have received. Words cannot express our deep feelings.

"Personally I feel particularly the responsibility that has fallen on me as President of the British Orthopaedic Association. It is perhaps a lucky coincidence that this should have happened for it is true to say that orthopaedically I am more than a little bit American in my background. A considerable part of my orthopaedic apprenticeship was in Ann Arbor for five years. Here I started the more serious study of our Art under the watchful eye of your former president Carl Badgley. He was and still is a great teacher and a good master to whom I am glad to pay my respects today.

"Now Mr. President, may I say something in general terms about this conference. We are concerned with people, techniques and ideas and, as Dr. Samuel Johnson said, ideas come first in importance. Perhaps in Washington we might also put an *L* in the word and recognize the place of *Ideals*. What we do and think here you can be sure is paralleled in engineering, law, chemistry, and commerce. We have got to find ways of working together without dominance by any community of the way of life or thought or way of speech of other communities. We give respect to the others' individuality making allowances for differences. This is not co-existence: it is creative co-operation. This is a meeting of Orthopaedic Associations of the

English-Speaking World—a selection of the orthopaedic associations it must be admitted and we should not presume to speak for all of the others. We should remember The American Academy of Orthopaedic Surgeons and, in the British Commonwealth, the young developing associations of India, Pakistan and the new nations of Africa.

"Be that as it may, we speak the same language—a wonderful language because of its elasticity and flexibility—its variations and shades of meaning—a language to which notable enrichment has come from the New World. In this our several nations are very lucky for it makes possible such a convention as this enabling us to understand each other, to find the littleness of our divisions, to learn the greatness of our common inheritance in language and in the work we do.

"Our two groups of societies, the American and those of the British Commonwealth, have been responsible in different ways for a remarkable infant. To be more particular your association Mr. President and mine—but yours in a much larger degree—have produced a very vocal child; a sort of Siamese twin—*The Journal of Bone and Joint Surgery*. We should not pursue too far the peculiar circumstances of its birth. Its origin in the early years of this century as *The American Journal of Orthopaedic Surgery* leads to the time exactly forty years ago when it became simply *The Journal of Orthopaedic Surgery* as the official organ of both the American and British Orthopaedic Associations. All of you are familiar with its later progress during the last ten years. This must surely be unique in the medical literature of the English-speaking World. For this we in the British Commonwealth are also grateful to The American Academy of Orthopaedic Surgeons for the great and powerful part they have played.

"Long may this joint effort continue. It is a particular pleasure for us that, as a result of our discussions during the last weekend, we will be able to continue in the future under conditions of cooperation which fully satisfy the criteria of understanding and creative effort that I have already mentioned.

The President of The British Orthopaedic Association, Norman Capener, with Sir Walter and Lady Mercer.

"Another of our achievements has been that of the Travelling Fellowships. I hope that there will be opportunities for discussion of the future of this scheme and in what ways it might be modified. That the exchange has been of the greatest worth and enlightenment no one can deny. That it should continue, you will agree, is vitally important. These men have done a great service as ambassadors of their countries. They have gained intellectually and in fellowship, and as in all true friendships they have given immeasurably. Each country has sent abroad some of the cream of its younger surgeons. We must see to it that the cream is not curdled.

"I wish there were time to say something about another problem which gives some of us occasional anxiety: it is the future of orthopaedics itself. Perhaps in our personal discussions we can exchange ideas. Today orthopaedics is very different from what I knew in Ann Arbor thirty years ago. Tuberculosis and osteomyelitis now—thank God—are nearly gone and poliomyelitis is going; but other departments of medicine are taking over fields in which traditional orthopaedics lead the way. To take only one field, physical medicine, for us and I think also with you, we must be vigilant and recognize our responsibilities for the whole care of our patients even outside the strictly surgical requirements of their cases.

"Be that as it may—we must remember our duties as teachers and while we may concern ourselves properly with the infinitely small, with the biomechanical and clinico-physical back-

ground, let us not forget the needs of those many men who come to us from underdeveloped parts of the world and who still see tubercle and have big problems in rehabilitation.

"Finally Mr. President, I would like to say: long may our joint efforts in orthopaedics continue, above all in presenting the ideals of English-speaking co-operation which is the great hope of the world in the future."

The ceremony then terminated and the members of each of the five Associations adjourned to hold the Executive Session of their respective organizations.

Joint Meeting of the Board of Trustees
The Journal of Bone and Joint Surgery, Inc.,
and the Executive and Members of the British Editorial Board

When the December issue has come off the press, been bound, and distributed to The Journal's almost 12,000 subscribers throughout the world, British-American collaboration in joint publication will have continued uninterruptedly for ten years.

As a business enterprise The Journal has proved to be a going concern. In point of service, with respect to meeting the publication and educational needs of orthopaedic surgery, The Journal has striven to provide a suitable means for the recording of orthopaedic achievement. It has endeavored to be of educational value, both locally and internationally, as a record and through the inevitable interchange of ideas. It, therefore, seemed fitting and proper that the principles and details of agreement under which copublication had been conducted should be re-evaluated with especial thoroughness and agreement reached whether or not to continue copublication. Heretofore Annual Meetings of the two Editorial Boards had always been

Robert W. Johnson, Jr., and Joseph Freiberg.

John R. Moore and Arthur B. LeMesurier.

constructive. With these considerations in mind, the Executive and Members of the British Editorial Board met with the American Board of Trustees of The Journal on May 10, at the Hotel Belvedere, in Baltimore—immediately before the Joint Meeting of the Associations in Washington. Present were Sir Walter Mercer, Chairman of the British Board, Philip Wiles, H. Jackson Burrows, Norman Capener, John Fairbank, Roger Gariepy, D. Lloyd Griffiths, R. I. Harris, Professor J. Trueta, Denys Wainwright, and Miss Jean Barnes, Editorial Secretary of the British Board. Of the American Board of Trustees there were present Robert W. Johnson, Jr., Chairman, D. M. Bosworth, G. A. Caldwell, E. L. Compere, K. O. Haldeman, and J. S. Speed. Present also was Mr. John A. Reed, Managing Editor of the American Volume.

Shortly after the meeting had been opened, Sir Reginald Watson-Jones addressed the group by tape recording made in London. He reviewed the aims and achievements of copublication and urged that nothing interfere with continuation of the collaboration.

After due deliberation and with confidence and enthusiasm it was unanimously agreed to continue the collaboration. Agreement with respect to subscription rates and number of issues per volume (beginning in 1959 to be twelve each year, four British and eight American) had been facilitated through correspondence during the preceding two years. At this meeting it was reached unanimously. Each board will carry its share of copublication responsibility with wide financial as well as editorial independence.

After the meeting, the two Boards dined together at the Mount Vernon Club, guests of Dr. and Mrs. Robert Johnson, Jr.; a memorable occasion, the charm, friendliness, and warmth of congeniality of which will not soon be forgotten.

On Sunday evening, May 11th, another memorable occasion, the American Board of Associate Editors, past and present, were hosts to the members of the British Editorial Board, past and present, at a banquet in the Club Room of the Hotel Shoreham, Washington. Present

also was Prof. Adam Gruca, Corresponding Editor of Poland. Dr. Frank Berry, Assistant Secretary of Defense, Health and Medical, from the United States, was Guest of Honor, and speaker of the evening.

The evening was one of relaxation and good cheer amidst the renewal of many cherished associations, and the formation of many new ones.

The Exchange Fellows

When, in 1947, a closer association of British and American orthopaedic surgeons began to take form, a plan was conceived of alternating exchange visits between the two countries, at intervals, by select groups of young orthopaedic surgeons. Thoroughly trained and experienced in the orthopaedic surgery of their respective countries, these men would tour the orthopaedic clinics of the other's country. There they could become familiar with the concepts and practice and come to know the orthopaedic surgeons. Through the resulting interchange of

William Tobin and Adam Gruca.

Sir Walter Mercer and Marcus Stewart.

J. S. Speed and Edwin F. Cave.

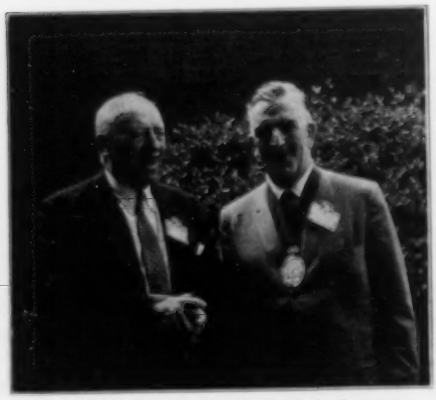
Frederic C. Bost and David M. Bosworth.

ideas it was felt that the surgery of each country would be stimulated and acquire an accelerated and sounder growth. Such has seemed to be the result. The Exchange Fellows have become traditional; each year, alternately, a delegation travels from the clinics of one country to the clinics of the other.

This year, five Exchange Fellows of The Commonwealth visited clinics of the United States and Canada: Martin Stuart Brett, F.R.C.S. of Salisbury, England, Robert Alexander Bremner, F.R.C.S. of London, Robert Owen, F.R.C.S. of Liverpool, Noel Jackson Blockey, F.R.C.S. of Glasgow, and Manuel Lunz, F.R.C.S. of Johannesburg, South Africa. Wherever they went in their six weeks' tour of the North American continent they were warmly welcomed and wheresoever they went they won the respect and affectionate regard of their Canadian and American hosts. As guests at the Joint Meeting they appeared in Washington where they received a hearty welcome. It seemed as though they knew and were on the friendliest terms with everybody. They gave a good account of themselves at the Annual Banquet, adding to the joy of the occasion.

Social Activities and Visits to Points of Interest in and About Washington

Contributory to the general happiness and enthusiasm were the many and varied social and recreational activities and the visits to points of general and special interest in and about Washington. In addition to the receptions of the Presidents of the American and Canadian Orthopaedic Associations, to which all were invited, there was an out-of-doors reception at the British Embassy and a tea at the Embassy of New Zealand given by the Ambassador and Lady Munro. On Monday, May 12, came Mrs. Eaton's luncheon for new members' wives. Especially for the ladies was a morning coffee and reception at Dumbarton House and the magnificent Dumbarton Oaks Gardens, given in honor of the wives of the Ambassadors from



Philip Wilson and J. B. Colquhoun.

D. L. Griffiths at Mount Vernon.

A group of visiting orthopaedists at the Dumbarton Oaks Gardens.

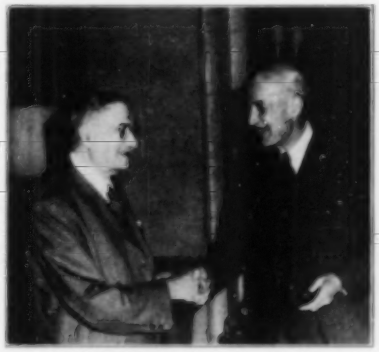
the English-speaking nations. Luncheon and fashion show in the Palladium Room of the Shoreham proved popular. In and about Washington there were visits to the National Gallery of Art, the Pan-American Union, the Lincoln and the Jefferson Memorials, the Smithsonian Institute, the Tomb of the Unknown Soldier who gave his life in the first World War, the Folger Library, the Washington Cathedral, the Islamic Center, and various other places of special interest, beauty, and significance. Farther from the city, tours to Mount Vernon, the home of George Washington, to Williamsburg, the old capitol of Virginia, fully restored in all its old colonial beauty, to the Gettysburg Battleground, to Manassas, to the United States Naval Academy

at Annapolis, to Rosecroft, Oxon Hill, Maryland, for harness racing, to Griffith Stadium to see professional baseball, and other places of varied interest.

All of these and many others were accorded full measure of popularity. Each had been thoughtfully and carefully planned by the General and Social Committees on Arrangements and by the very felicitous and able Committee on Social Activities whose Honorary Chairman was Mrs. George Eaton and whose Chairman was Mrs. William Tobin. Private parties, large and small, some planned, some spontaneous, in homes in and about town or at the Shoreham, where and whenever they could be sandwiched in, added so much to sociability and led to the foregathering of many kindred spirits. New contacts were made; the bonds of former friendships strengthened. How much they must mean; how lasting many will be.

The National Institutes of Health

On May 13, the Scientific Sessions were held at the National Institutes of Health in nearby Bethesda, Maryland. Here took place the Symposium on Arthritis under the Chairmanship of Mr. Helfet, President of the South African Orthopaedic Association.



Arthur Steindler and Arthur LeMesurier.

N. J. Blockey and M. S. Brett.

Philip Wiles, J. G. Shannon, and M. Lunz.

In welcoming the members of the Associations and guests, Dr. Joseph J. Bunim, Chief of Clinical Investigations, National Institute of Arthritis and Metabolic Diseases, spoke as follows: "On behalf of Dr. James A. Shannon, Director, and of the staff of the National Institutes of Health, I extend to you a most cordial welcome.

"Dr. Shannon's associate, Dr. Joseph Smadel, who was originally scheduled to speak at this time has been called away on urgent business. He asked me to convey his regrets and his hope that your meeting shall be a complete success.

"We were quite pleased when your local Program Committee suggested that you pay us a visit. My own particular organization, the National Institute of Arthritis and Metabolic Diseases, was chosen to participate in the scientific program this morning because our work seemed to be more akin to your interests than that of our sister Institutes. The brief glimpse of our activities you will thus obtain should be considered as more or less representative of the research programs being conducted throughout the seven Institutes which form the National Institutes of Health.

"At this point it may be helpful, if I explain very briefly the organization and mission of N.I.H.

"We are but one of four bureaus which constitute the United States Public Health Service. Our mission is research. The other three bureaus are concerned with classical public health activities such as quarantine, communicable disease control, sanitation and environmental health, and with operating a number of general and special hospitals, including institutions for the care of merchant seamen and coast guardsmen, American Indians, the victims of Hanson's Disease, and for narcotic addicts.

"In addition to our own program of research, N.I.H. assists the research of universities and medical schools throughout the Nation. This is done by means of financial grants for medical research and a very extensive program of fellowship and traineeship stipends. The total in-

Winthrop Phelps, Frank Dickson, and Warren White.

volves an expenditure of more than $200 million annually appropriated to us by our Federal Legislature. About one-fourth of this sum goes into our own research here at Bethesda; the remainder into research grants, training grants and fellowships in medical colleges and universities.

"The Clinical Center itself (the building you are in) is a combined research hospital and laboratory designed especially to foster collaboration between the many laboratory and clinical disciplines essential to the comprehensive investigation of many important medical problems. Our patients are referred to us by their own physicians and are accepted because their history and diagnosis are specifically suited to one of our studies.

"At the National Institute of Arthritis and Metabolic Diseases, a staff of approximately 135 scientists are actively engaged, full-time, in clinical investigation and basic laboratory research. Clinical investigation encompasses studies in arthritis and other rheumatic and collagen diseases, endocrine diseases, disorders in mineral and energy metabolism and hematology. The research program of the arthritis and rheumatism branch includes a multi-disciplinary attack on rheumatoid arthritis; its pathogenesis, pathologic characteristics, serological abnormalities, the nature of the mucopoly-saccharide-protein complex in synovial fluid, steroid metabolism and evaluation of new steroid and non-steroid therapeutic agents. Studies of the genetic, dietary and endocrine factors in the pathogenesis of osteo-arthritis in experimental animals are in progress and will be reported to you this morning by Dr. Leon Sokoloff. The nature of the inborn error of metabolism in gout and in hereditary connective tissue diseases such as Marfan's syndrome, is being investigated in laboratories employing disciplines in enzyme chemistry.

"I understand that this is the second joint meeting in six years of the Orthopaedic As-

sociations of six English-speaking countries. You may well be proud of the successful organization of this distinguished international body and of the admirable and effective fellowship exchange program sponsored by your association. We are pleased and privileged to have you visit us at the N.I.H. and wish you sincerely a most successful meeting."

Dr. Bunim's report on "Hazards of Steroid Therapy" discussed by Dr. Frank E. Stinchfield completed the excellent Symposium. Buses then transported everyone from the meeting to the National Naval Hospital where, at the Naval Officers Club, there was a most cordial reception and luncheon. Tours followed of the Naval Hospital with special attention to the Tissue Bank, and of the National Institutes of Health.

At the Officers Club of the National Naval Medical Center, Bethesda, are: A. R. Shands, Jr., James A. Dickson, Herman F. Johnson, Paul C. Colonna, Albert C. Schmidt, Norman Capener, and H. Jackson Burrows.

H. Sakellaures, Martin Brett, and M. Lunz.

The Walter Reed Army Medical Center

On May 15, in the Walter Reed Army Medical Center, there was held the Symposium on bone tumors. Mr. John Colquhoun, President of the Australian Orthopaedic Association, was in the chair. Welcome to the Walter Reed was extended by Major General James P. Cooney, Deputy Surgeon General of the Army, to the members of the Associations and

guests. There then followed a thoroughgoing survey of the present status of the classification and treatment of bone tumors in a series of presentations of deep interest before a packed theater.

Luncheon followed at the Officers Club, Walter Reed Army Medical Center.

During the afternoon, Dr. Lent Johnson of the Institute of Pathology (by invitation) presented: "General Biological and Field Theory of Bone Tumors" before a filled theater. A tour of the Institute of Pathology followed a tour of the Army Prosthetic Research Laboratory, and later a color television presentation.

All were indebted to Captain Thomas M. Foley, Jr., who conducted the tours at the N.I.H. and the U. S. Medical Center; to Colonel S. Thomson and Colonel Sterling Ritchey who conducted the tours through the Walter Reed Army Medical Center.

The Annual Banquet

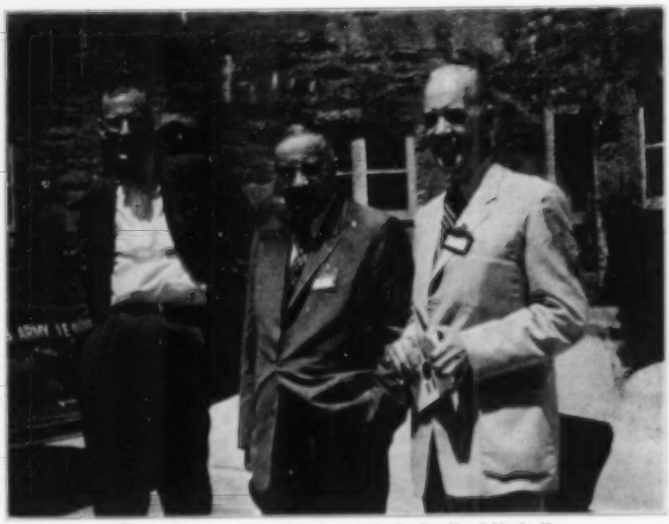
The combined Annual Banquet of the Associations took place at the Shoreham on May 15. Present were over 1,000 members, their wives, and guests. The occasion was a memorable one. After dinner speakers were the Presidents of the five Associations. Each gave expression to the cordiality and stimulation which had prevailed throughout the meeting, the

Dr. and Mrs. James Dickson and Dr. and Mrs. Mather Cleveland.

deeper understanding of each others people which had been made possible by the close associations, and the warmth of friendliness which had come during the days together in Washington. Dr. R. I. Harris introduced the Exchange Fellows; Mr. Martin S. Brett and Mr. Noel J. Blockey responded, telling of their travels through the clinics of the United States and Canada and expressing for themselves and their fellow travelers their thanks and appreciation. Dr. William J. Tobin, speaking on behalf of the Local Committee on Arrangements, of which he was Chairman, acknowledged the thanks of all for the outstanding way in which the Meeting had been arranged, giving the credit to the members of his committee. Dr. John Adams acknowledged the thanks of all for the superb work of the Washington Orthopaedic Club, of which he is President, in making the Meeting in so many ways so successful, and for their almost unbelievably warm-hearted and generous hospitality.

Post-Meeting Tours

The Joint Meeting closed on Friday, May 16. The next morning many of the visiting surgeons boarded buses and with their wives set forth to tour various clinics in eastern cities of the United States and Canada. In each city visited the ladies were entertained by the wives of the host surgeons while their husbands attended the clinics; the remainder of each day was then devoted to parties, buffets, dinners, and visits when, as often happened, travel schedules permitted. Tour I included Baltimore, Wilmington (where ninety-three arrived by bus alone), Atlantic City, Philadelphia, and New York City, ending after two days in the latter city on May 21. Tour II continued on from New York, visitors leaving for Canada by train. After a night of travel on the sleeper, May 22 was spent in Toronto and after



F. P. Dewar, Leo Lucas, and C. Leslie Mitchell.

At the Alfred I. duPont Institute are John Colquhoun, A. R. Shands, Jr., and A. J. Helfet.

a second night on the sleeper, May 23 was spent in Montreal where Tour II ended. Continuing on from Montreal those who had chosen to go all the way arrived in Boston the morning of May 24 and visited there the 24th, 25th and 26th, entraining on the latter night for New York City and the end of the tours. When the Tour III tourists hit Boston there were thirty-three surgeons and nine wives which speaks well for the endurance of the visitors and their wives, or for the high quality of the clinics and warmth of hospitality, or both. Surely after a day's rest, in between clinics in Boston, all seemed none the worse for the busy ten days entour and all did seem happy and satisfied. Certainly they gave their hosts the keenest pleasure. Everywhere the hosts hated to see them go.

The Committees

For the excellence of the general planning of the Meeting, the host Associations felt deeply indebted to the General Committee on Arrangements of which the Chairman was Dr. A. R. Shands, Jr., and the members of which were: George W. Armstrong, George O. Eaton, R. I. Harris, H. Relton McCarroll, Leonard T. Peterson, Carter R. Rowe, Harold A.

Sofield, T. Campbell Thompson, and William J. Tobin. For the breadth of vision and extremely careful attention to detail in making local arrangements high praise was due to the Local Committee of which Dr. W. J. Tobin was the Chairman, Dr. Leonard T. Peterson, the very able Co-chairman, and the hardworking and efficient members of which were: Murray M. Copeland, Paul B. Magnuson, and Col. Milton S. Thompson. The Post-Meeting Tours were organized and arranged by the indefatigable Dr. Shands. For the pleasant social activities and the beautifully planned and understandably described tours to points of interest in and about Washington all of which proved so rewarding, all felt indebted to the Ladies Activities Committee of which Mrs. George O. Eaton was Honorary Chairman, Mrs. William J. Tobin was Chairman, and the members of which were Mrs. Murray M. Copeland, Mrs. Paul B. Magnuson, Mrs. Leonard T. Peterson and Mrs. Milton S. Thompson. The Hotel Arrangements Committee under the Chairmanship of Dr. and Mrs. Peterson included: Mrs. Austin B. Rohrbaugh, Jr., Dr. and Mrs. John P. Adams, Registration, Dr. Austin B. Rohrbaugh, Jr., Audio-Visual, and Mrs. Thomas M. Foley, Luncheon and Fashion Show. The other Activities Committee, under the Chairmanship of Dr. and Mrs. Murray M. Copeland included Mrs. Marvin M. Gibson; Dr. and Mrs. Julius S. Nevaser, transportation; and Dr. and Mrs. Milton C. Cobey, special events; Dr. and Mrs. John P. Adams, tennis; Dr. Allan M. McKelvie, hospitality for overseas guests; Mrs. Allan M. McKelvie, tea, at New Zealand Embassy and reception at Dumbarton House; Captain Thomas M. Foley, Jr., activities at the National Institutes of Health, and the U. S. Naval Medical Center. Lastly, Colonel Milton S. Thompson and Colonel Sterling J. Ritchey organized the activities at Walter Reed Army Medical Center. To the members of the Washington Orthopaedic Club and their wives words seemed inadequate to express the gratitude of all for their helpful cooperation and unfailing cordiality in all phases of the operation of the Meeting.

The Proceedings of the Scientific Sessions and the Audio-Visual Program will appear in the December issue of The Journal.

THE ORTHOPAEDIC RESEARCH SOCIETY

The Annual Meeting of The Orthopaedic Research Society was held at the Cornell Medical School and the Waldorf-Astoria Hotel, New York City, on January 31 and February 1, 1958. The following officers were elected.

President: C. Howard Hatcher
President-Elect: Robert D. Ray
Secretary-Treasurer: Paul H. Curtiss, Jr.

The Orthopaedic Research Society welcomes all who may be interested in applying for membership. The requirements for membership are primarily a present and continuing interest in research related to the field of orthopaedic surgery. The Society is particularly desirous of receiving applications from younger investigators and from Canadian and other orthopaedic surgeons who feel that they will be able to meet the responsibilities of continuing

membership. At the present time, membership is automatically forfeited by an active member if he (a) fails to attend three consecutive meetings without suitable excuse, and (b) if for five consecutive years fails to submit to the Program Committee a subject for presentation.

Applications for membership should be sent to the Secretary, Dr. Paul H. Curtiss, Jr., 2065 Adelbert Road, Cleveland 6, Ohio.

The following new members were elected:

John A. Blosser
J. Wallace Blunt, Jr.
Chalmers R. Carr
O. Donald Chrisman
Ernest Burk Evans
John Joseph Flanagan
Charles J. Frankel
Melvin Jacob Glimcher
Beckett Howorth
William Jelier Hutchison
Jacob F. Katz
Patrick G. Laing
William J. Tobin

The next meeting of The Orthopaedic Research Society will be held immediately preceding the 1959 Annual Meeting of The American Academy of Orthopaedic Surgeons in Chicago, Illinois.

Abstracts of the papers presented at the Scientific Sessions follow; abstracts of those papers presented at the Combined Program of The Orthopaedic Research Society and The American Academy of Orthopaedic Surgeons were printed with one exception in the Proceedings of The American Academy of Orthopaedic Surgeons in the June 1958 issue of The Journal.

The Sensory Nerves of Deep Hand and Foot Structures. Dr. Donald Stilwell, Jr.,[1] studied sensory nerve endings and their distribution in deep structures of the hands and feet of man and monkey by gross dissections and by supravital methylene blue stains. Fasciae, aponeuroses, muscles and tendons, retinacula, ligaments, flexor-tendon sheaths, fiborous joint capsules, and aponeurotic expansions of extensor tendons were examined microscopically. For the most part these fibrous structures are supplied by digital or cutaneous nerves or by both.

A regionally associated sensory triad of free, small Pacinian and Ruffini-type nerve terminations was found in all joint capsules (similar to the innervation of all major joints), flexor tendon sheaths, retinacula, and extensor tendon expansions. It is thus apparent that very abundant proprioceptive signals emanate from a variety of deep fibrous structures of the hand and foot. Digital and cutaneous nerves, heretofore considered by many to innervate only skin, convey practically all signals for motion and position sense from the hand and foot to the central nervous system. This should be of interest to surgeons dealing with surgical and traumatic conditions of the limbs. It is now recognized that signals from nerves of muscle probably do not reach consciousness.

In addition to their contribution to kinesthetic sensation, some of these sensory signals almost undoubtedly contribute to muscular reflex arcs at a spinal-cord level and to the control of voluntary muscular activity at cerebellar and cortical levels.

Discussion was presented concerning the roles of these and other sensory nerves of the limbs in the functions of the nervous system during easy standing, normal locomotion, digital ataxia as a residuum of peripheral-nerve lesions, and pain in deep hand and foot structures. It was pointed out that in comparison with other deep structures of the limbs and trunk, the hands and feet are extravagantly innervated; this is consistent with the unique sensory and motor capacities of these members.

Note: This material is more fully exploited in two recent publications: Am. J. Anat., **100**: 59-73 and 75-99, 1957.

The Prenatal Development of the Bones and Joints of the Human Foot. Dr. Ernest Gardner[2], Dr. D. J. Gray, and Dr. Ronan O'Rahilly stated that the lower-limb buds are present at about four weeks after ovulation, and a cellular axial condensation (blastema) is present in the limbs a few days later. By five weeks, the tarsus is present as a commom blastemal mass from which digital prolongations extend. Between five and one-half and seven weeks, the various muscles, nerves, joints, and ligaments differentiate, the skeletal elements chondrify, and, by the end of the embryonic period (seven weeks), the foot closely resembles that of the adult.

The development of the joints of the foot is similar to that of the hip and knee. The cellular blastema persists between the cartilage as homogenous interzones. These become three-

1. 751 Menlo Avenue, Menlo Park, California.
2. Wayne State University, Detroit, Michigan.

layered before cavitation begins. Although cavitation begins in many joints early in the fetal period, the cavities may not be clearly outlined for several weeks. Most ligaments are present by the end of the embryonic period.

The metatarsals begin to ossify first (about ten menstrual weeks), as do the distal phalanges also about this time. The proximal phalanges ossify next (thirteen to fourteen weeks) and, very much later, the middle phalanges. The calcaneus may show a periosteal center by thirteen or fourteen weeks, but its endochondral center appears several weeks or months later, as do those of the talus and cuboid. Sesamoid bones are chondrified by ten or eleven weeks. Cartilaginous fusions are common. The middle and distal phalanges of the little toe are fused in about 50 per cent of the cases. Other fusions may occur also, for example, talus and sustentaculum tali. The tarsal cartilages become vascularized by thirteen to fourteen weeks even though they do not ossify until later.

The Effect of Pressor and Depressor Drugs on Intramedullary Bone Pressure. Dr. Arthur H. Stein, Jr.[3], Dr. Harry C. Morgan, and Dr. Roberto F. Porras presented a study of the variation of intramedullary bone pressure. The tibia of adult dogs was used for the study. The effect of various pressor and depressor drugs was investigated. The effects of adrenalin, nor-epinephrine, pituitrin, histamine, amphetamine, acetylcholine, and atropine were observed. The recordings were made by the Sanborn electromanometer and included simultaneous observations on systemic arterial-blood pressure.

From this study it was concluded that intramedullary bone-marrow pressure levels are dependent upon: (a) systemic-blood pressure, and (b) the patency of the nutrient artery and possibly other small vessels supplying the bone.

Intramedullary pressure may be lowered by simultaneously lowering the systemic-blood pressure by injection of histamine. The marrow pressure can be increased simultaneously with the systemic pressure by injection of amphetamine.

Intramedullary pressure may be lowered while there is a simultaneous rise in the systemic-blood pressure. This effect can be produced by adrenalin and nor-epinephrine. It is believed that the marked fall in marrow pressure following adrenalin or nor-epinephrine is probably due to vasoconstriction of the nutrient vessels supplying bone, particularly the major nutrient vessel.

Cranial Reconstruction with Ethylenediamine Treated Bone. Dr. Lloyd A. Hurley[4] and Dr. Hubert L. Rosomoff implanted ethylenediamine treated bone grafts of autogenous, homologous, and heterologous origin in large defects (five by six centimeters) in dog skulls. Results were compared with those from use of untreated grafts of fresh, autogenous bone. The order of biological acceptance of the grafts was: fresh, autogenous, untreated; heterologous, ethylenediamine; homologous, ethylenediamine treated; and autogenous, ethylenediamine treated. No untoward tissue or clinical responses were observed. The ethylenediamine treated grafts were revascularized, remodeled, and incorporated progressively with time so that solid union of the graft to host was achieved. It was concluded that ethylenediamine treated bone, regardless of species source, was an effective graft. Some advantages and disadvantages of ethylenediamine treated bone were recognized. The authors felt that the results of this study were sufficiently rewarding to justify clinical trial in man.

The Specificity of the Macromolecular Aggregation State of Collagen in Calcification. Dr. Melvin J. Glimcher,[5] Dr. Alan J. Hodge, and Dr. Francis O. Schmitt postulated a general concept of the basic physical chemical mechanism initiating mineralization in biological structures based on observations of the specific interrelationships between reconstituted and native collagens and metastable calcium-phosphate solutions.

The initiation of calcification is depicted as a process of heterogeneous nucleation of apatite crystals from a metastable calcium and phosphate solution by the highly specific stereochemical configuration and crystal structure of native-type collagen fibrils. That the nucleation of the inorganic crystallites requires a precise juxtaposition of groups in the organic matrix was demonstrated by using collagen reconstituted in a number of different fibrillar crystal forms: native (640 angstrom-unit axial repeat), 220 angstrom-unit axial repeat, unstructured fibrils, fibrous long spacing, and segment long spacing. Of these forms, only the native-type fibrils (representing one type of aggregation state of the tropocollagen macromolecules) were capable of inducing the formation of apatite crystals when exposed to metastable solutions of calcium and phosphate.

That the specificity lies in the manner of packing of the collagen macromolecules and not in the molecule itself was further demonstrated by the failure of collagen macromolecules and random aggregations of collagen macromolecules both in solution and in the solid state to induce a phase change.

3. Washington University School of Medicine, St. Louis, Missouri.
4. The New York Orthopaedic Hospital, New York 32, N. Y.
5. Massachusetts General Hospital, Boston, Massachusetts.

Bone, demineralized with versene under suitable conditions, has also been shown capable of inducing crystal formation.

The ability to initiate mineralization does not appear to be specific for bone collagen, however, a variety of reconstituted native-type collagens from tissues normally uncalcified can be mineralized *in vitro*. Under similar physical chemical conditions, however, freshly dissected untreated collagen fibers from rat-tail tendon do not calcify although this same collagen, when extracted and reconstituted in the native configuration, is able to mineralize.

Preliminary results were also presented showing the effect of altering the macromolecular aggregation state of native-type collagens by chemical and physical means and their effect on the property of initiating this specific phase change.

This suggests that all collagenous matrices in biological structures are inherently capable of initiating calcification, but under normal conditions other components of the ground substance inhibit and control this process.

Early results of experiments which maintained collagen architecture in tissues but effectively removed a good deal of other components of the ground substance substantiate this concept.

The orientation of apatite crystals with respect to the collagen-fiber axis, while quite striking in well oriented adult bone, appears to be the result of crystal growth in an oriented organic matrix and not due to any epitactic relationship between apatite and collagen. The process of crystal orientation thus appears to be unrelated to the specific nucleation phenomena which initiate mineralization.

NOTE: Some of these findings have been previously reported in the Proc. Nat. Acad. Sciences, **43**: 860, 1957.

The Water Content of Bone. II. The Division of Bone Water Between the Marrow Vascular Osteocyte Space and the Calcified Osteoid Matrix. DR. ROBERT A. ROBINSON[6] and Mr. Stuart R. Elliott stated that in an earlier publication (J. Bone and Joint Surg., **39-A**: 167-188, Jan. 1957) it was shown that the bone specimens from the tibial cortex of puppies and dogs which were free of periosteum and medullary marrow had a variable density between 2.05 and 1.35 when the specimens were hydrated. On the other hand, when the specimens were dry and when the density of these specimens was derived in such a way that the volume of the dry specimen only included the volume occupied by the dry solids in the specimen, then the density of such specimens was fairly constant being about 2.33 ± 0.14 in the bones from newborn puppies, and in the bone from adult dog it averaged 2.35 ± 0.05.

The logical conclusion drawn from these findings was that bone from most normal dogs has a similar density when dry and that the dry substance in a whole bone specimen has a fairly similar composition. However, in a hydrated bone specimen this dry substance of fairly uniform average composition can somehow or other be associated with more or less water. Various amounts of dry bone and water are combined to yield the widely varying densities of fully hydrated bone specimens.

This present paper reported investigations in which bone specimens of known hydrated and dry density were studied in the microscope. The photomicrographs were enlarged and, by geometric methods, it could be determined that the bulk of the water in a hydrated bone specimen was located in the marrow-vascular and osteocyte spaces rather than in the calcified bone matrix of the specimen. All bone specimens are porous to some degree, containing canaliculi, lacunae, and marrow vascular spaces. It is in these pores of the bone sample that the bulk of the water resides.

A Study of Osteoporosis in the Experimental Animal Employing Strontium-85. DR. J. H. CHRISTIE[7] and DR. L. J. CORDREY conducted a study of osteoporosis in mice using Sr^{85}.

Normal values for the calcium, phosphorus, and protein content of bone were determined by the ashing of mouse femora. A parallel study conducted on castrated mice of the same age revealed 40 per cent decrease in Ca and P ratio compared with the normals and an increase in protein.

Serial x-ray studies were conducted on normal mice and castrated mice. No demonstrable change was noted.

Several factors regarding the deposition of Sr^{85} in bone were determined. It was established that there is a biological exchange of Sr^{85} in the mouse and that this exchange is multiphasic. In addition, the effect of animal age was studied, and it was established that the younger the animal the longer was the biological half-time. Distribution studies on animals brought to autopsy from one hour through fourteen days after the injection of Sr^{85} intraperitoneally showed that bone is the primary and selective site of deposition. During the first twelve hours after injection the amount in the soft tissues dropped very rapidly, corresponding favorably with the first phase of equilibrium and excretion in the biological turnover.

6. The Johns Hopkins Hospital, Baltimore 5, Maryland.
7. 10515 Carnegie Avenue, Cleveland 15, Ohio.

Studies on castrated mice four and one-half months and older, showed that the excretion of Sr^{89} is significantly altered when the strontium is injected one month or more following castration. The retention of strontium in this group is 30 per cent greater than in the non-castrated group, and this would seem to indicate replacement of mineral lost secondary to metabolic change following castration.

Although further study is indicated, it is believed a sensitive technique for evaluation of metabolic alteration in bone, in the experimental animal, has been demonstrated.

Observations on Physical Properties of Cartilage. Dr. J. W. Blunt, Jr.[8], pointed out that if a joint is to be replaced, the prosthesis should replace the supporting matrix and the elastic cartilage of the joint. In order to obtain an effective cartilage substitute, the properties of cartilage must be determined by use of the engineering methods of the plastic and rubber industries to give findings which can be interpreted. In this preliminary report, findings in fourteen knee joints and thirty-two hip joints from adult human cadavera were given. The thickness of the articular cartilage of the femoral head averaged 2.5 millimeters, while that of the tibial plateau was 2.8 millimeters. The Shore A Durometer reading of hip cartilage was 80; that of knee cartilage was 75. The significance of the Shore A Durometer reading as pertaining to elasticity and general properties of a plastic or rubber material was pointed out. It was noted that specimens from older patients gave a higher durometer reading than those from young patients. Specimens from patients who were active up to the terminal illness had a higher reading than specimens from those who had been immobilized for prolonged periods. Other American Society for Testing Materials standards were cited, but results were too limited to justify conclusions.

Sulphur Metabolism in Cartilage. II. Sulphate Studies in Cartilage Strips Incubated In Vitro. Dr. O. Donald Chrisman[9], Dr. Rose R. Coelho, and Dr. Charles O. Bechtol investigated the breakdown of the chondroitin sulphate complex in hyaline cartilage slices *in vitro* and tried to relate this to the breakdown of cartilage in degenerative osteo-arthritis. Although much previous work has been done on the incorporation of S^{35} into cartilage ground substance, no information has been reported on the total sulphate content of such slices. Costal cartilage from puppies was incubated at 37 degrees centigrade in S^{35} Tyrodes solution for twelve hours; only .33 of 1 per cent of the total sulphate was incorporated by the strips, while 27 per cent of the sulphate was lost. Overheating or NaCN protected against this sulphur loss, while iodoacetate had no effect. They believed that these findings provide good indirect evidence for the presence of a chondrosulphatase in cartilage, this being the first time this enzyme activity has been reported in this tissue. This enzyme may well be involved in the early histological changes in degenerating cartilage—partial loss of metachromasia and fibrillation with loss of elasticity. It may also help to explain the finding in a previous paper of statistically significant elevation of joint-fluid sulphate above serum sulphate in patients with degenerative arthritis.

Metabolic Studies in Orthopaedic Patients. Dr. George E. Spencer, Jr.[10], Dr. Harvey Krieger, Dr. William E. Abbott, and Dr. Stanley Levey pointed out that patients undergoing bone trauma have shown a rather marked negative nitrogen balance. No specific way has been found to offset this negative nitrogen balance. Six patients who had bone trauma have been studied by means of metabolic balance techniques at University Hospitals of Cleveland. In each patient the balance was kept regarding water, sodium, potassium, nitrogen, 17 hydroxycorticosteroids, and weight. Four patients remained in negative nitrogen balance throughout the study, whereas two were in essential balance. The four patients who were in negative balance had a poor intake and did not take in the amount of calories and nitrogen recommended by Rhoads. The two patients in whom the nitrogen balance was maintained did take in the amount of nitrogen and calories as recommended by Rhoads. All patients showed changes in weight and nitrogen balance that fairly well paralleled their dietary intake. The patients showed no gross abnormalities in their electrolyte and fluid balances throughout the study. There was no correlation between nitrogen balance deficits and the urinary excretion of 17 hydroxycorticosteroids. From these studies it appears that factors other than bone trauma and adrenal overactivity affect the patient's metabolic response. The factors which are of primary importance are nutritional intake, fever, immobilization, and the preoperative nutritional state.

Earlier Weight-Bearing in Legg-Calvé-Perthes Syndrome. Correlated Clinical, Mechanical, Biopsy, Circulatory, and X-Ray Studies. Dr. Charles Weer Goff[11] emphasized that, as man's hip permitted greater extension, related to bipedal locomotion, a small, firm area of bone came to transmit man's weight across the pelvis onto the femur. This area has been identified

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9. 264 Elm Street, Northampton, Massachusetts.
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by stresscoat and split-line studies. It is smaller in man than in the gorilla and baboon, and still smaller in the chimpanzee, orangutan, and the spider monkey. Size and location seem to correlate with the degree of bipedalism.

Circulatory studies indicate a selective arteriovenous system nourishing the femoral head and metaphysis of children. The lateral-posterior epiphyseal region is more abundantly supplied, correlating with the geographical location of the weight-bearing zone.

The avascular disorder of Legg-Calvé-Perthes disease manifests its effect by means of selective patterns, visible on early x-ray plates. These patterns may be classified into three types:

1. Type A in which the entire epiphysis becomes necrotic (37 per cent);
2. Type B in which both epiphyses are affected (13 per cent);
3. Type C in which a part of the bone center is spared, either by remaining viable or by rapidly re-ossifying (50 per cent). In the last type the identified weight-bearing plate and its reinforcing trabeculae are usually spared.

Therefore, treatment is dependent upon the degree of and location of the avascular bone. In Type A, prolonged recumbency allows time for the supporting structures to re-form. In Type B, recumbency is necessary to prevent the second hip from taking the added burden of weight-bearing before it is structurally strong enough to do so. In Type C, with a partially affected epiphysis, much less non-weight-bearing is required; in fact, the patient seems to recover more rapidly if guarded crutch-walking is permitted at an early date. In Dr. Goff's series recumbency averaged eight months.

The critical phase of the disorder with regard to prognosis is the initial moment of observation. If the destruction has just begun, the prognosis is far better than if there exists considerable disorganization of the growth disc and the epiphysis. In either case the duration of recumbent care should be appropriate to the individual patient.

The Influence of Transplantation Immunity on Bone Homografts. Mr. John Chalmers[12] carried out an experiment to see whether homogenous-bone grafts were affected by a pre-existing state of transplantation immunity in the host and also to investigate the ability of the homogenous-bone grafts to evoke transplantation immunity.

The progress of fresh homogenous-bone grafts in normal rats was compared with that of similar grafts in rats which had previously received a homogenous-skin graft from the same donor. In the normal rats, two separate phases of new-bone formation occurred: early (from four to fourteen days and terminating in death of the new bone), and late (the new bone developed with increasing frequency after four weeks). In the rats which had received skin grafts no new bone developed.

Freeze-dried homogenous-bone grafts did not show the early phase of new-bone formation, but in a few grafts of five months and older, new bone of the late phase was observed.

The survival time of homogenous-skin grafts was used as an index of the level of immunity.

Following a fresh homogenous-bone graft, a skin graft from the same donor underwent rejection at six days; this was similar to that of a second set homogenous-skin graft in rats. Following the insertion of a freeze-dried homogenous-bone graft, a homogenous-skin graft from the same donor survived significantly longer than first set homogenous-skin grafts.

It was concluded that fresh homogenous-bone grafts liberate tissue antigens and that bone and skin of an individual have antigens in common, so that either is able to sensitize a host against the other. These antigens are inactivated by freeze-drying.

The death of the early homogenous-graft new bone can be explained by the development of transplantation immunity in the host against the homogenous graft. (This incidentally demonstrates that this new bone arises from graft cells.)

The late phase of new-bone formation from homogenous grafts probably arises from metaplastic changes in the host tissues.

COMBINED MEETING OF THE ORTHOPAEDIC RESEARCH SOCIETY AND THE AMERICAN ACADEMY OF ORTHOPAEDIC SURGEONS

The Practical Importance of Synovial-Fluid Analysis. Dr. J. George Furey, Dr. William S. Clark and Miss Katherine L. Brine (J. Bone and Joint Surg., **40-A:** 715, June 1958).

The Extra-osseous and Intra-osseous Blood Supply of the Talus. Dr. Robert A. Haliburton, Dr. C. Roger Sullivan, Dr. Patrick J. Kelly, and Dr. Lowell F. A. Peterson (J. Bone and Joint Surg., **40-A:** 715, June 1958).

Growth in Transplanted Bone. Dr. Charles F. Thompson, Dr. Edward V. Schaffer and Dr. Frank B. Throop (J. Bone and Joint Surg., **40-A:** 715, June 1958).

Changes in Respiratory Function with Scoliosis. A Preliminary Report. Dr. Thomas Gucker, III (J. Bone and Joint Surg., **40-A:** 716, June 1958).

12. Royal National Orthopaedic Hospital, London, England.

Calcinosis Circumscripta. A Local and Metabolic Study. Dr. Robert W. Bailey (J. Bone and Joint Surg., **40-A:** 716, June 1958).

The Phasic Activity of the Muscles of the Lower Extremity and the Effect of Tendon Transfer. Dr. J. Robert Close [13] pointed out that the intermittent contractions of the muscles of the lower extremity during walking are associated with the events of the walking cycle. If continuous oscillograms are recorded from individual muscles and plotted according to their occurrence during the stance and swing phases, one has a display of the phasic activity of the muscle. By this method, each muscle contraction as the subject walks, is readily identified with its phase. In the normal subject, the anterior muscles of the leg are swing-phase muscles; posterior or flexor muscles are stance-phase muscles. In the thigh, the quadriceps is characteristically a stance-phase muscle, while the hamstring muscles are all basically of the swing phase.

When tendon transfer in the lower extremity is contemplated, the question often arises whether one can violate the patterns of phasic behavior and expect a functional transfer. If an extensor muscle such as the anterior tibialis is transferred into the heel, its phase would have to change from swing to stance to be an effective transfer. Also, if a flexor muscle such as the posterior tibialis is transferred anteriorly into the dorsum of the foot, it would have to convert its phasic activity from stance to swing to be an effective transfer.

The ability of a transfer to perform the function, for which it is intended, is well known. The peronaeus longus muscle transferred to the dorsum of the foot may act as an excellent voluntary dorsiflexor. The same muscle may fail completely to act during the swing phase of walking when its action is required to dorsiflex the foot and prevent foot-drop.

Muscles were studied preoperatively as well as following tendon transfer in many cases. Dual internal wire electrodes were used, connected by shielded cable to the preamplifier of a cathode-ray oscilloscope. The oscilloscopic trace was photographed with a continuous-recording oscilloscope camera. The vertical output of the oscilloscope was connected to the amplifier of a sound motion picture camera.

The method revealed the phasic activity of the muscle, the duration of each muscle contraction, and the electrical intensity of motor-unit activity.

All of the normal muscles in the lower extremity were studied; but the main purpose of the work was to study muscles of the lower extremity following tendon transfer. Over 100 muscles representing the conventional tendon transfers were tested: (1) extensors to the dorsum of the foot, (2) flexors to the dorsum of the foot, (3) flexors to the calcaneus, (4) anterior tibialis to the calcaneus, (5) combinations of the first four groups, and (6) hamstrings to the patella.

Phasic transfers, such as extensor muscles transferred into the dorsum of the foot, promptly regain their preoperative desirable swing-phase activity. The degree of recovery and effectiveness of the transferred muscle is reflected by the intensity of electrical activity and the population of motor units in the postoperative tracing. Other phasic transfers, such as peroneal muscles or flexor muscles transferred into the calcaneus, similarly retain their preoperative phasic activity. In general, non-phasic transfers, such as the biceps muscle to the patella, the anterior tibialis to the heel, flexor muscles to the dorsum of the foot, tend to retain their preoperative pattern of phasic activity, thus failing to make the desired conversion to the phase of the muscle for which they are substituted. There were several exceptions:

1. When the anterior tibialis was transferred to the calcaneus, excellent stance-phase conversion was demonstrated in four of thirteen patients. This conversion was observed only when the procedure was done as a single tendon transfer.

2. When the peronaeus longus was transferred to the dorsum of the foot, only one patient of twenty acquired involuntary swing-phase activity. The others retained their stance-phase pattern or acquired a certain amount of electrical activity throughout the entire walking cycle.

3. When the peronaeus brevis was transferred to the dorsum of the foot, a remarkable conversion to the swing phase of walking was demonstrated in seven of nine patients.

13. 2929 Summit Street, Oakland, California.

AMERICAN ACADEMY FOR CEREBRAL PALSY

The Annual Meeting of the American Academy for Cerebral Palsy was held in New Orleans, Louisiana, on November 24 to 27, 1957, under the Presidency of Dr. Nicholson J. Eastman. Dr. William T. Green was installed as President. The following officers were elected at the meeting: Dr. Alvin J. Ingram, *President-Elect;* Dr. Samuel B. Thompson, *Treasurer;* and Dr. Raymond R. Rembolt, *Secretary*. The 1958 meeting will be held in Providence, Rhode Island.

Sunday, November 24, a conference, The Role of Kernicterus in Cerebral Palsy, was presented. Dr. Chester A. Swinyard was Chairman, and the moderators were Dr. Pearce Bailey and Dr. Nicholson J. Eastman. The following papers were included:

Experimental and Clinical Observations of Hyperbilirubinemia. Dr. Richard L. Day and Dr. Louis Johnson.

Mechanisms and Significance of Hyperbilirubinemia in the Newborn with Reference to Kernicterus. Dr. Wolf W. Zuelzer.

Contribution of Neuropathology to the Pathogenesis of Kernicterus. Dr. Webb E. Haymaker and Dr. Angel Pentschew.

Electroencephalographic and Psychological Aspects of the Kernicteric Child. Dr. Donald B. Lindsley.

Auditory Deficits of the Kernicteric Child. Dr. William G. Hardy.

Clinical Characteristics of the Kernicteric Cerebral-Palsied Child. Dr. Meyer A. Perlstein.

The discussors were Dr. Sidney Carter, New York, N. Y.; Dr. Harold Westlake, Evanston, Illinois; Dr. T. F. McNair Scott, Philadelphia, Pennsylvania; Dr. Leslie B. Hohman, Durham, North Carolina; and Dr. Arnold S. Breakey, New York, N. Y.

The following Instructional Courses were given:

Diagnosis, Classification, and Principles of Treatment of Cerebral Palsy. Dr. Meyer A. Perlstein.

Bracing for Patients with Cerebral Palsy. Dr. Robert A. Knight.

Techniques of Therapy in Occupational Therapy and Physical Therapy. Theory. Dr. William Cooper and Dr. Leon I. Charash.

Techniques of Therapy in Occupational Therapy and Physical Therapy. Practice. Dr. Solomon Winokur.

Neuroanatomical and Physiological Basis for Cerebral Palsy. Dr. Chester A. Swinyard.

Management of Spastic Hemiplegia. Live Clinic. Dr. Lenox D. Baker.

Ambulation Techniques in the Patient with Cerebral Palsy. Live Clinic. Dr. George G. Deaver and Thelma Mikalov, R. N.

Ocular and Related Disabilities in Cerebral Palsy. Dr. Arnold S. Breakey.

Neurosurgical Measures in Cerebral Palsy. Dr. Russell Meyers.

Orthopaedic Surgery in Cerebral Palsy. Upper and Lower Extremities. Live Clinic. Dr. Jack K. Wickstrom, Dr. Harry E. Barnett, and Dr. Lenox D. Baker.

Electroencephalography in Cerebral Palsy, Especially as Related to Seizures. Dr. Donald B. Lindsley.

Management of the Athetoid Patient. Live Clinic. Dr. Winthrop M. Phelps.

At the scientific luncheons for non-members and paramedical personnel, Dr. Martin F. Palmer was Moderator. The following lectures were included:

Modalities of Management in Cerebral Palsy. Dr. Temple Fay and Dr. Harriet E. Gillette.

Education of the Child Handicapped with Cerebral Palsy. Dr. Maude A. Buckingham.

Paramedical Therapy in Cerebral Palsy. Dr. Martin F. Palmer.

A Symposium, Vocational Training and Rehabilitation Problems in Cerebral Palsy, Dr. Margaret H. Jones as moderator, was held for members and guests.

The Child with Cerebral Palsy, a closed two-hour television clinic, was presented on the evening of Tuesday, November 26. The participants were Dr. Nicholson J. Eastman, Dr. Meyer A. Perlstein, Dr. George G. Deaver, Dr. Margaret H. Jones, Dr. Russell Meyers, Dr. Winthrop M. Phelps, Dr. Harold Westlake, and Dr. Leslie B. Hohman.

Summaries of scientific papers follow:

The Role of the Reticular Formation in Perceptual and Motor Functions. Dr. Donald B. Lindsley [1] reported that, in the study of brain injury, and particularly in cerebral palsy, there is need to consider new concepts of brain function which have developed from neurophysiological and psychophysiological investigations.

The descending influences of the brain stem reticular formation suggest revision of clinical diagnostic evaluations based on observed motor deficits. The facilitatory and inhibitory influences of widespread areas of the brain funneling through the reticular formation suggest possible revisions in thinking about the type of lesions which produce spasticity, athetosis, rigidity, and ataxia. The tendency to think solely of spasticity as a manifestation of cortical damage, and athetosis as a subcortical lesion, requires further consideration and analysis. Tests of autonomic function, of differential motor and psychomotor reactions, and of sensory, perceptual, and integrative analysis may help to locate and delimit lesions and thus better define the involvement.

Dr. Lindsley discussed the ascending reticular activating system in relation to experiments which bear not only on general arousal (sleep-waking) and general alerting (mobilization and attentiveness), but also on specific alerting (focused attention and lock-in) mechanisms. He gave special emphasis to a possible role of the ascending reticular activating system in perception and learning, and in drive-motivational and affective-emotional contexts. He stressed the linkages of the reticular formation with hypothalamus, hippocampus, and non-specific thalamic nuclei of diffuse projection.

Dr. Lindsley placed some emphasis upon over-all integration involving the reticular formation, its centripetal and centrifugal sources of activation, and the network of corticifugal and reticular feedback controls which monitor sensory influx and motor outflow. The electrocortical rhythms and their associated excitability cycles provide a temporal integrating and screening mechanism.

From these considerations, Dr. Lindsley felt that there is hope for a more rational approach to alleviating drugs, and the possibility of developing a rehabilitative motor-training program based upon potentialities rather than upon a striving toward impossible goals.

The Use of Respiratory Equipment in the Control of Breathing Dysrhythmia in Athetosis. An Exploratory Study. Dr. Robert Harrington [2] stated that the purposes of his investigation were to study certain characteristics of breathing irregularities in patients with athetosis and to determine whether the use of certain respiratory equipment would be helpful in establishing more satisfactory breathing patterns, especially during speech.

The subjects were thirteen patients with athetosis from three to twenty-eight years old. Respiratory equipment included a tank respirator, two types of portable respirators, and an intermittent positive pressure breathing device. Depending upon the availability of the patients, the experimental period ranged from three months to twenty-three months.

Dr. Harrington explained that the procedure included a cineroentgenographic study of diaphragmatic movement, kymograph recordings of breathing movements, tape recordings, and certain measures of ventilation.

He reported the following tentative conclusions: (1) There is limited diaphragmatic excursion and incoordination of the diaphragm in patients with athetosis, (2) the requirements of speech intensify breathing irregularities; (3) the tank and both types of portable respirators seemed to establish more rhythmical, slower, and deeper breathing movements; and (4) the intermittent positive pressure breathing apparatus, used as an adjunct to the respirator, seemed to augment the intake of air.

Dr. Harrington felt that the results seemed to justify a comprehensive study of respiration in patients with cerebral palsy. He suggested that basic physiological information should be obtained.

1. University of California, Los Angeles, California
2. Orthopaedic Hospitals, Los Angeles, California

Pattern of Regeneration of Muscle *in Vitro* from Progressive Muscular Dystrophy Patients, as Compared to Normal Human Skeletal Muscle. Dr. R. S. Geiger [3] and Dr. J. S. Garvin [4] reported that biopsy specimens of muscle tissue from fifteen patients with progressive muscular dystrophy have shown strikingly different regenerative properties as compared with normal adult skeletal muscle in *in vitro* experiments. The dystrophic muscle cells in culture have a shorter dormancy period, are more granular, and do not develop cross striations. Except for dystrophic myotonia cells, they rarely show spontaneous contraction. After the first month in culture, or seven to ten days after having been subcultured, the dystrophic cells undergo marked hypertrophy and may reach one to two millimeters in length, with sixty to eighty, or more, nuclei present in a single cell, produced amitotically. This often coincided with the appearance of longitudinal striations. The hypertrophied cells then break up and degenerate. This process of abortive regeneration extends over a period of three to four weeks in subculture. The cells from pseudohypertrophic muscular dystrophy patients could only be successfully subcultured through one passage. The authors felt that under identical conditions normal skeletal muscle cells reach sizes up to 300 micra, show periodic budding, spontaneous contractility, and cross striations. Normal cells can be maintained indefinitely in culture, and can be readily subcultured.

Other types of muscle tissue from patients with muscular involvements, such as spinocerebellar degenerative disease or myositis, did not show the abnormal patterns of growth in tissue culture.

Hamstring Contracture in Cerebral Palsy. Dr. Henry H. Banks [5] and Dr. William T. Green [6] reported a follow-up study of the correction of hamstring contracture with flexion deformity of the knee done at the Children's Hospial in Boston between 1940 and 1954. Fifty-five procedures had been performed on twenty-nine patients. Follow-up material was available for twenty-two males and seven females. Eighteen patients were seen at a follow-up clinic more than two years after surgery, and sufficient data were available in the records of nine additional patients to adequately determine the end result of their surgery. Twenty-one were seen more than five years, and twelve, more than ten years, from the date of operation.

The authors explained that the operation consisted in a sliding or fractional lengthening of the hamstrings with an additional fractional lengthening of the tendinous origin of both heads of the gastrocnemius in fourteen instances. They emphasized the importance of postoperative care, including physical therapy, bivalved night casts, and supervised walking.

They concluded that hamstring contracture with flexion deformity of the knee could be corrected by hamstring lengthening. Adequate follow-up care and cooperation are essential to maintain the correction and functional improvement.

General Considerations in the Treatment of Cerebral Palsy with a Discussion of Reflex Therapies. Dr. William S. Hatt [7] said that among the substitution methods in the treatment of hemiplegia are the Rood and Temple Fay techniques, the former depending upon the neurological principle of facilitation. Movement to be gained is facilitated by stimulation of the particular dermatome in question by utilizing a one-inch paint brush, cut short, with a rubber ball attached to the handle. Brushing is followed by petrissage and this is followed by pounding over the bone with the rubber ball. This technique is found to be especially applicable in patients with athetosis because of its essentially pleasant nature.

Temple Fay's techniques, which make use of primitive reflexes, have been utilized especially in the face-down position for finger function, and the Marie-Foix reflex has been utilized for foot, knee, and hip. These two techniques compliment each other admirably.

Dr. Hatt noted that since the use of Marie-Foix reflex, operative lengthening of the heel cord in a patient with cerebral palsy has been rare.

Dr. Hatt divided his paper into the following sections: (1) techniques of relaxation; (2) range of motion; (3) increased muscle strength; (4) kinesthetic sensation; (5) orthopaedic appliances; and (6) gait.

Electromyographic Patterns in Cerebral Palsy. Dr. Meyer A. Perlstein [8], Dr. Marcos Turner [9], and Dr. Harry Elam [10] stated that electromyographic studies of individual muscles in the various forms of cerebral palsy have not had much clinical significance. Except for an increased stretch reflex in spasticity, there were no characteristic findings in the various forms of brain injury. The present study is one in which an attempt is made to classify

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10. Northwestern University, Evanston, Illinois

the various patterns of muscle action in spasticity and athetosis, using an Offner Transistor Electroencephalograph. The authors made electromyographic studies, using eight simultaneously placed electrodes.

They felt that their observations indicated that there is no regular pattern for muscle action in patients with athetosis. At times, rest potentials can be obtained; at times they cannot. There may be co-contraction of muscles at one time and altogether different types of reaction at a different time. In contrast to athetosis, the patterns in spasticity are quite constant. They are characterized by a persistence of crossed reflexes and by spread of movement in one muscle to other contiguous groups of muscles in a definite pattern. Thus, eliciting a knee jerk in normal patients results in electromyographic activity in only the quadriceps. When, however, there is a spastic limp, it is found that there is also activity in the hamstrings, in fact, to a greater extent there than in the quadriceps. This pattern of muscle action is present to some degree in the normal infant. The authors felt that it appeared that the patterns seen in spastic patients are those seen in normal infants and characterized by a spread of the impulse to the antagonist muscles and to contiguous muscle groups.

Work Adjustment Training for the Handicapped. Dr. William Gellman [11] in discussing our work-oriented society, said that each adult expects to achieve economic independence through productive work. Unemployed persons, whatever the reason—disability, age, accident—are devaluated and tend to regard themselves as failures.

Apparently unemployable handicapped persons require more than occupational training if they are to overcome the feeling of misfortune and become employable. The acquisition of skills without the values and attitudes necessary for productive work is not sufficient to increase employability. Disabled individuals who have never had the opportunity to work or who are fearful of work need the opportunity to develop a work personality in a work situation which permits learning. A vocationally oriented workshop appears to be best adapted for this purpose.

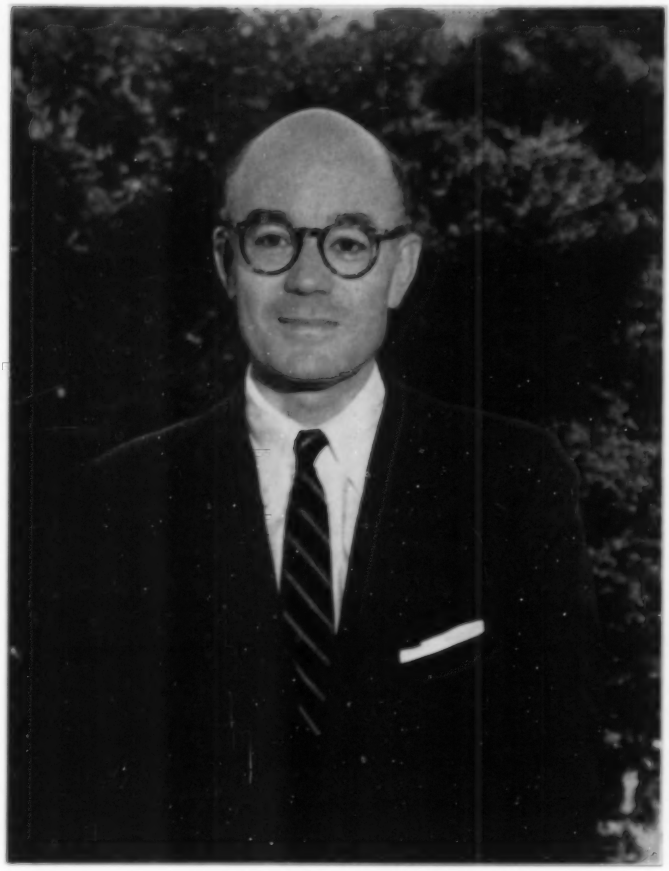
Dr. Gellman described the Vocational Adjustment and Evaluation Center of the Jewish Vocational Service of Chicago, a vocationally oriented workshop which helps handicapped persons overcome psychological barriers to employment. It simulates a true work situation with regard to hours, wages, conditions at work, and supervisory-worker relationships. The program consists of a two-week evaluation program and an eight-week work adjustment program.

Over a six-year period, approximately 65 per cent of the 700 physically, mentally, or emotionally handicapped persons who completed the eight-week adjustment program became employable. Studies of the continuity of employment for those deemed employable indicated that 90 per cent are working one year after leaving the Center. Testing before and after the adjustment program indicates that changes in employability occur without major changes in the basic personality structure.

The Center serves individuals with all types of disabilities, with multiple disabilities being most common. Approximately one-half of the persons seen have never worked, and an additional 40 per cent have been unemployed for one year or more. Ages ranged from seventeen to sixty-two, with an average age of twenty-seven. Intelligence quotients varied from forty-five to 137, with a median of seventy-one.

Dr. Gellman concluded that most handicapped persons can learn to develop an adequate work personality; they can function productively if they are prepared psychologically; individual barriers to employability are inability to see oneself as a worker or to assume the role of a worker; employers will accept disabled persons who have demonstrated through workshop experience that they are able to function; and the greater the degree to which a workshop simulates a true work setting, the better it will serve as a learning device for increasing the employability of handicapped persons.

11. Jewish Vocational Service of Chicago, Chicago, Illinois



ROBERT A. KNIGHT, M.D.
1914—1958

On November 21, 1914, in Carter, Oklahoma, Lynnie and William Knight became the parents of a male child, Robert Allen Knight. Suddenly on April 13, 1958, the life of this man and orthopaedic physician whom we knew as Bob Knight and the life of his only child, Robert Spencer Knight, were wiped out.

Few will doubt that intellect is one of the requirements of greatness. None will doubt that this man was intellectual. Energy is needed to turn that intellect into knowledge. If that knowledge is to be put to a useful purpose, talent must be one of his possessions. If the talent is to be used wisely, the possessor must have wisdom and if it is to be used to its fullest capacity, he must be motivated and must have the ability to carry a load. If his contributions and attainments are to be used by others, he must be a teacher. If they are to live after him, he must be a writer. That he has left this heritage is evidenced by his numerous contributions to orthopaedic literature and as the Associate Editor of *Campbell's Operative Orthopaedics*. In his achievements Bob Knight demonstrated a blend of talent and motive and of ability fused with a zeal that few have. He used his achievements wisely to become a great orthopaedic physician. In the true meaning of the word, what did he have that made this fine man so rare a physician? He was calm and honest; he was kind and he had understanding; he was blessed with a love for all things, a love that people could feel and that gave them peace of mind and understanding. Bob Knight was Christ-like. With the same dedication he was husband, father, son, and friend.

Early in life, Bob faced tragedy; when he was but ten years of age, his father died. Thereafter he had to win his own way. This and the strong influence of his mother seemed to mold the child. It is significant that she was a teacher. Her son was graduated by the University of Oklahoma with honors, including Phi Beta Kappa. He had the gift of curiosity and had an indomitable purpose in his work. For sheer scope of interest, few matched

him. He was a master at learning. He knew what to learn and learned it precisely. He served a rotating internship at Touro Infirmary in New Orleans, Louisiana, where one of his surgical services was under Alton Ochsner. It would have been interesting to have seen these two dynamos at work. Of Bob Knight, Alton Ochsner said, "He is a splendid boy with an interest in orthopaedics. In addition to being an excellent worker, he is one who does not have to be told to do things as he has plenty of initiative." He took his first training in orthopaedic surgery at the Duke University Medical Center in Durham, North Carolina, where his record contains the following statement: "If in each generation a Service has one great officer, it is fortunate indeed. We have had ours." From Duke, Bob Knight went to the Willis C. Campbell Clinic and to the Orthopaedic Department at the University of Tennessee in Memphis, Tennessee, where, except for one year in Baltimore with Winthrop M. Phelps in cerebral palsy, he lived the productive professional career so well known to all orthopaedists and to the world.

As a son, he fulfilled his mother's ambitions and attained the character and growth she inspired.

As a husband he was understood, his partner contributed to and shared in his successes and joys. He loved and was loved with a devotion known to few men.

As a father he set the example of a gentleman and had the patience and understanding that go with love and dreams.

As a friend he had charm and zest for life with an ability to share the satisfaction of accomplishment and the pleasure of living. He was admired and professionally esteemed. Although he had not the time nor the freedom from his work to fill all his dreams and ambitions, in the time allotted, he left no work undone. This man, except for fate, was destined to be the leader of his generation in orthopaedics. His life and his death leave a challenge to those who must try to fill his place.

L.D.B.

I. WILLIAM NACHLAS
1894—1958

Bill Nachlas was a man with many friends as he went through life giving of himself and his professional skill. If the measure of worth is in drams of service to mankind, his filled a cup.

He was born in Baltimore October 1, 1894, and showed early promise of achievement. Privately tutored for a time, he entered the Johns Hopkins University in 1910, then proceeded to the Medical School, where he was graduated in 1918. Inspired by Dr. W. S. Baer, he decided to dedicate himself to orthopaedic surgery. After completing his residency at Johns Hopkins, he gave unsparingly of his energy to his private practice; his reward was the personal satisfaction of work well done. His busy life was interrupted by service in World War I as Lieutenant in the Medical Corps and in World War II as Lieutenant Colonel.

There was always time for investigation to enhance the knowledge of orthopaedic surgery and time to encourage and stimulate younger men in research. His own contributions to the medical literature attest to his energy and fruitful efforts in that direction.

His affiliations give evidence of his absorbing interest in his profession. He was a member of The American Orthopaedic Association, The American Academy of Orthopaedic Surgery, the Orthopaedic Forum, the Southern Medical Association, the Correspondence Club, the Baltimore City Medical Society, and the Medical and Chirurgical Faculty of Maryland. He was the founder of the Orthopaedic Forum, a closely-knit group of his orthopaedic friends, and of this association he was especially proud.

He was actively associated with most of the Baltimore hospitals. His formal teaching at the Johns Hopkins University Medical School, where he was Associate Professor of Orthopaedic Surgery, was supplemented by other tasks. He was Chief Orthopaedist at the Sinai Hospital and at the Levindate Home for Incurables. He was Visiting Orthopaedic Surgeon at the Children's Hospital, Inc., the Washington County Hospital, the Union Memorial Hospital, and several others.

Bill never married. He was one of a large family and his joy was with his family. With them, and with many young medical students, he shared both his monetary rewards and his professional generosity.

He was stricken suddenly at the height of his career and on April 20, 1958, at the age of sixty-three, he died at the Johns Hopkins Hospital where he spent so many happy years and where his spirit still moves with those he loved.

R. E. L.

HENRY FRANZ ULLRICH
1903—1958

Dr. Henry Franz Ullrich was born in Baltimore, Maryland, on November 17, 1903, and died on March 24, 1958, aged fifty-four, after only six weeks of illness.

Dr. Ullrich was educated in the schools of Baltimore having graduated from the Baltimore Polytechnic Institute ("A" engineering course), and the Johns Hopkins University; he received his Doctor of Medicine Degree from the University of Maryland in 1929 and served two years in the University Hospital as interne and assistant resident. From 1931 to 1936 he trained in the New York Orthopaedic Hospital under Dr. Hibbs, Dr. Farrell, and Dr. Alan Smith receiving the degree of Doctor of Science in Medicine from Columbia University, College of Physicians and Surgeons. From this time until his death, Dr. Ullrich practiced orthpaedic surgery in Baltimore except for the years 1942 to 1945 when he was in the armed services in Australia, the Philippines, and Woodrow Wilson General Hospital (Staunton, Virginia) as a Colonel and Chief of Orthopaedic and Surgical Services.

Doctor Ullrich was a member of the American Medical Association, Medical and Chirurgical Faculty of Maryland, among the general medical organizations, and The American Orthopaedic Association, The American Academy of Orthopaedic Surgeons, the Interurban Orthopaedic Society, the Association of Bone and Joint Surgeons, and the American College of Surgeons, of which he was a governor. Since 1954 he was President of the Blue Shield of Maryland, and was also a Trustee of the University of Maryland Endowment Fund for the Medical School. Being a member of the staffs of twelve Baltimore hospitals, he was known and respected by all medical personnel in the city as an excellent surgeon and teacher. He was Associate Professor of Orthopaedic Surgery in the University of Maryland Medical School and was certified by the American Board of Orthopaedic Surgery in 1940.

Henry was a most lovable character with a grand sense of humor and always had a good story to accompany any situation and hence was a welcome companion at all times; he never burdened one with his own troubles, presenting to the last a cheerful and optimistic front. One of his greatest assets was the meticulous care and genuine interest in his patients and their problems; his patients came first and in consequence they all admired, respected, and loved him, be they rich, poor, big, or small. Nothing was too much trouble for him and he was always ready to accept more than his share of administrative or technical responsibility. He developed a large service in scoliosis at the Kernan Hospital; for these patients he had unusual success in decreasing or correcting their deformities; he had started studies in designing clothes for girls with curvatures, so that the deformity could be less obvious, which was most appreciated by these patients.

His family was the joy of his life and he was devoted to his charming wife and to his two daughters, Elizabeth and Hazel. Although he was an early morning riser and operator, he always managed to spend time with his family.

He was a thirty-second degree Mason, a member of St. David's Episcopal Church, and the Gibson Island and University Clubs.

All who associated with Dr. Ullrich, medical or otherwise, held him in great esteem for his honesty, keen wit, simple judgment, and his kindness to all, yet he was unswerving when he believed he was right and would tolerate no trickery. He had a passion for promptness and efficiency in technique; hence he was an expert surgeon.

Dr. Ullrich's many friends all over the world will miss him very much, but those who were intimately associated with him were deeply saddened by his passing and are reminded daily of their great loss. We sympathize deeply with his family.

A. F. V.

News Notes

The Board of Trustees of The Journal of Bone and Joint Surgery announce with pleasure the apointment of **Dr. Thornton Brown** as **Editor of The Journal. Dr. William A. Rogers** has retired with the life status of **Editor-in-Chief Emeritus.**

The next Annual Meeting of **The American Academy of Orthopaedic Surgeons** will be held in Chicago, Illinois, January 24 through 29, 1959.

The Annual Meeting of the **American Society for Surgery of the Hand** will be held at the Palmer House, Chicago, Illinois, January 23 and 24, 1959. The provisional program follows:

Friday Morning, January 23

Heterogenous Tendon Grafts. J. Edward Flynn, M.D., and Charles C. Child, M.D., Boston, Massachusetts;

Primary Repair of Flexor Tendons. Claude Verdan, M.D., Lausanne, Switzerland;

The Study of Flexor Tendons and Their Coverings in the Process of Repair. Martin Entin, M.D., Montreal, Canada;

Experimental and Clinical Studies on the Application of Monomolecular Cellulose Filter Tubes to Create Artificial Tendon Sheaths in the Hand. Franklin L. Ashley, M.D., Los Angeles, California;

The Pathogenesis of Dupuytren's Contracture: Experimental and Further Clinical Investigations. Robert D. Larsen, M.D., and Joseph L. Posch, M.D., Detroit, Michigan.

Friday Afternoon, January 23

Selective Surgical Procedures in the Cerebral Palsied Hand. Alfred B. Swanson, M.D., Grand Rapids, Michigan;

Objective Methods of Evaluating Hand Sensation and Their Use in Reconstructive Surgery. Erik Moberg, M.D., Gothenburg, Sweden;

Tendon Transfer Procedures in the Paralysed Hand. William L. White, M.D., Pittsburgh, Pennsylvania;

Tendon Transfers for Ulnar-Nerve Injuries. J. Leonard Goldner, M.D., Durham, North Carolina;

Vascular Injuries Relating to the Hand and Forearm. Robert S. Shaw, M.D., Boston, Massachusetts.

Saturday Morning, January 24

The Versatile Cross-Finger Pedicle Flap. H. Dean Hoskins, M.D., Oakland, California;

Reconstruction of a Grasping Mechanism Following Extensive Loss of Digits. Elden C. Weckesser, M.D., Cleveland, Ohio;

Reconstruction of a Digit Following Loss of All Fingers with Preservation of the Thumb. G. N. Lassar, M.D., St. Louis, Missouri;

Symposium: Acute Trauma to the Hand and Its Complications. *Moderator:* William H. Frackelton, M.D., Milwaukee, Wisconsin.

The **Western Orthopedic Association** will meet in Portland, Oregon, October 22 through 25, 1958.

The International Society of Orthopaedic Surgery and Traumatology will meet next in New York City, September 4 through 10, 1960. The headquarters hotel will be the Astor. Suitable and reasonable accommodations will be available at the Astor and nearby hotels.

The subjects for discussion at this meeting will be:

1. Congenital acetabular dysplasia;

2. Osteogenesis and treatment of delayed union and non-union in long bones;

3. Teaching and training in orthopaedic surgery and traumatology and the organization of hospital services.

There will be an associated audio-visual program, as well as scientific and commercial exhibits.

Travel to the United States may be arranged through the American Express Company.

Post-convention tours to nearby orthopaedic centers are planned.

Further information may be obtained by application to the Secretary of the Congress, Lee Ramsay Straub, M.D., 535 East 70th Street, New York 21, N.Y.

Exchange Fellowship Tour, 1958

Five young orthopaedic surgeons from Great Britain and the Union of South Africa completed a six weeks' tour of American and Canadian orthopaedic centers on May 10, 1958.

Those selected for this tour were: Martin Brett, Salisbury, England; Robert Bremner, London, England; Robert Owen, Liverpool, England; Noel Blockey, Glasgow, Scotland; and Manuel Lunz, Johannesburg, South Africa.

They were met in New York City on April 1 by Dr. Halford Hallock; their first week was spent touring the centers of that city. The tour of Canada included visits in Montreal and Toronto, after which they returned to the United States for several days' stay in Chicago and Rochester.

The tour included for the first time visits to orthopaedic centers in the South and Southwest. A few days were spent at the Campbell Clinic in Memphis, Tennessee, as they traveled from Oklahoma City, Oklahoma, to New Orleans, Louisiana. Programs were arranged at Durham, North Carolina, Chapel Hill, North Carolina, Wilmington, Delaware, and Philadelphia, Pennsylvania, before the Joint Meeting of the Orthopaedic Associations of the English-Speaking World in Washington. The weekend following the meeting was set aside for sightseeing and rest. One day was spent with Dr. Beckett Howorth in Stamford, Connecticut, before they sailed to England.

These gentlemen made an excellent and lasting impression on their hosts and hostesses everywhere. Martin Brett, spokesman for the group, summed up their impressions of the tour in these words: "The most important part of the experience was in meeting the men on their own ground, and leaving them having acquired a really personal interest in the associated names, faces, and places. The hospitality which our American hosts and hostesses extended to us was quite wonderful, especially in the way in which we were welcomed into their homes. This left us with a strong feeling of being unable to repay a heavy debt."

Many orthopaedic surgeons in America who are not members of The American Orthopaedic Association gave freely of their efforts, time, and money to help with the scientific programs and social functions as the Exchange Fellows of this and previous years have visited their cities. The Association is keenly aware of this generous participation and all members are grateful to these men and their wives who have contributed so much to the value and success of this project.

The **Exchange Fellowship Committee of The American Orthopaedic Association** invites applications from American orthopaedic surgeons for the Exchange Fellowships Tour to Great Britain in the Spring of 1959.

Requirements are: (1) United States citizenship, (2) completion of Part II of the Examinations of The American Board of Orthopaedic Surgery, and (3) applicants must be less than forty years old on December 1, 1958.

Requests for application blanks should be directed to Dr. J. Neill Garber, *Chairman*, Exchange Fellowship Committee, The American Orthopaedic Association, 806 Hume Mansur Building, Indianapolis 4, Indiana.

At the recent meeting of **The American Orthopaedic Association,** Dr. C. Leslie Mitchell, Detroit, Michigan, was inducted into office as President. The following officers were elected:

President-Elect: John Royal Moore, M.D., Philadelphia, Pennsylvania;
Vice-President: Keene O. Haldeman, M.D., San Francisco, California;
Secretary: Lee Ramsay Straub, M.D., New York, N.Y.;
Treasurer: Mather Cleveland, M.D., New London, New Hampshire.

Elected to membership in **The American Orthopaedic Association** were:
James E. Bateman, Toronto, Ontario, Canada;
Thornton Brown, M.D., Boston, Massachusetts;
Crawford J. Campbell, M.D., Albany, New York;
William C. Cooper, M.D., New York, N.Y.;
Joseph D. Godfrey, M.D., Buffalo, New York;
Floyd H. Jergesen, M.D., San Francisco, California;
Richard H. Kiene, M.D., Kansas City, Missouri;
Donald B. Lucas, M.D., San Francisco, California;
Ignacio V. Ponseti, M.D., Iowa City, Iowa;
Charles Rombold, M.D., Wichita, Kansas;
Frank B. Smith, M.D., Portland, Oregon.
Dr. Albert B. Ferguson, Sr., was elected to Honorary Membership.

A conference on **Bone as a Tissue** will be held October 30 and 31, 1958, at Lankenau Hospital, Philadelphia, Pennsylvania. The program follows:

Thursday, October 30

OSTEOPOROSIS

Chairman: Edward C. Reifenstein, Jr., M.D., Associate Medical Director, The Squibb Institute for Medical Research, New Brunswick, New Jersey.

Osteoporosis of Cushing's Syndrome. H. A. Sissons, M.B., Institute of Orthopaedics, London, England;

Hormonal Factors. Marshall R. Urist, M.D., Medical Center, University of California, Los Angeles;

Calcium Deficiency as a Cause of Osteoporosis. B. E. C. Nordin, M.D., University of Glasgow, Scotland;

Atrophy of Disuse. G. D. Whedon, M.D., National Institutes of Health, Bethesda, Maryland.

DYNAMICS OF CALCIUM METABOLISM

Chairman: Cyril L. Comar, Ph.D., Laboratory of Radiation Biology, Cornell University, Ithaca, New York.

Chemical Dynamics of Bone Mineral. W. F. Neuman, Ph.D., Department of Biochemistry, University of Rochester, New York;

Dynamics of Calcium and Strontium Metabolism in Man. Goran C. H. Bauer, M.D., Department of Orthopaedics, University of Lund, Malmö, Sweden;

The Role of Ground Substance in Calcification. I. Gersh, Ph.D., Department of Anatomy, University of Chicago;

Microscopic Metabolism of Calcium in Bone. John Marshall, Ph.D., Argonne National Laboratory, Lamont, Illinois.

Friday, October 31

ULTRASTRUCTURE OF BONE

Chairman: Friedrich Wassermann, M.D., Division of Biological and Medical Research, Argonne National Laboratory, Lemont, Illinois.

Electromicroscopy and Chemical Analysis. R. A. Robinson, M.D., Department of Orthopaedics, Johns Hopkins Hospital;

Fibrogenesis and Matrix Formation. Dr. Sylvia Fitton Jackson, Biophysics Research Unit, King's College, London, England;

Ultrastructure of Bone Mineral. Arne Enstrom, M.D., Department of Medical Physics, Karolinska Institute, Stockholm, Sweden;

Autoradiography. Pierre Lacroix, M.D., Department of Anatomy, Louvain, Belgium.

VITAMIN D, PARATHYROID, CITRIC ACID, CALCIUM, AND PHOSPHORUS

Chairman: John Howard, M.D., Department of Medicine, Johns Hopkins Hospital.

Parathyroid and Homeostasis of Blood Calcium. D. Harold Copp, M.D., Department of Physiology, University of British Columbia, Vancouver, Canada;

Vitamin D. H. D. Harrison, M.D., Department of Pediatrics, Johns Hopkins Hospital;

Citric Acid. Smith Freeman, M.D., Department of Biochemistry, Northwestern University, Chicago;

Phosphorus Metabolism. Franklin C. McLean, M.D., Department of Physiology, University of Chicago.

Book Review

DIE DIAFIXATION. K. Pap, Doxent Dr. Med. Hab. Budapest, Akademiai Kiado, 1956.

The title of this book comprises a term used by the author to specify a well known but little used method of internal fixation of shaft fractures. Refinements and applications of the method are described in detail. In *diafixation*, a Kirschner wire penetrates and fixes the fracture ends at the site of fracture; fixation is percutaneous and temporary. Advantages of the method are that surgical exposure of the fracture site is avoided, and that the procedure is rapid, taking on the average twenty or thirty minutes. Only simple and inexpensive surgical equipment is required. The method has the disadvantages that a plaster cast is necessary as supplemental fixation and that it is not suitable for comminuted fractures. It is not indicated for children under ten, but is very well tolerated in the aged.

The author analyzes the causes and the angles of displacement of various fractures, and points out that the direction of reposition must be opposed to that of displacement. *Diafixation* transforms the different forces acting at the fracture site into forces of compression, and it eliminates the torsion factor which predisposes to non-union. The essential technique is accurate reduction of the fracture fragments by manipulation through the skin; then transfixion by a diagonal Kirschner wire while the reduction is assiduously held. X-ray control is employed. The importance of traction in effecting the reduction is emphasized; a spring balance and a fracture table are very helpful. A Thomas wrench, or a modification called by the author a *reductor*, is the most valuable ancillary instrument. Other supplemental instruments are an awl and a bone hook, employed when necessary through a nick in the skin. The Kirschner wire is introduced through the soft tissues by means of a guide—a hollow needle the shank of which is attached to a handle for ease of manipulation. The author discusses in detail the correct angle at which the wire should traverse the fracture site; his mathematical formulae confirm one's mechanical judgment as to what should be the most stable position. Progression of the wire should cease after it has traversed the second cortex. Special cutting points to the wires are desirable in order to facilitate penetration of bone at an acute angle. One is not concerned with fixation of small fragments, but only with immobilization of fractures of the shaft. Two Kirschner wires, inserted criss-cross, should not be used since they prevent impaction.

While the cast is being applied and is setting, the external forces which were necessary to effect reduction are continued manually. The protruding end of the Kirschner wire is fixed in the cast; this is important. The wire is withdrawn after three to five weeks, occasionally later. Active exercises are started at once. However, the point is stressed that security of fixation is paramount and must not be jeopardized by too eager mobilization. Hinged casts are sometimes used to facilitate joint motion.

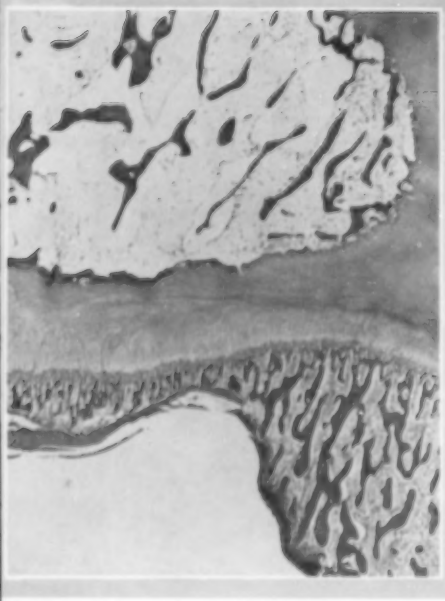
A portion of the book is devoted to analyses of the various methods of internal fixation of fractures and their different indications. The author philosophizes upon the relationship of the doctor to methods and to circumstances. His fracture work has been done in Budapest. He gives detailed descriptions of many specific cases in which *diafixation* has been used to advantage. The illustrations are detailed, and furnish the reader with a clear picture of much that is described in the text.

Fractures of all the major long bones, including the clavicle, have been treated successfully by *diafixation*. A series of 416 of these cases is evaluated in detail. Eliminated are the severe comminuted fractures, which would tend to decrease the favorable results; also eliminated are the uncomplicated fractures that were primarily stable and the readily healing fractures of children under ten, which would tend to increase the favorable results. In the 416 cases reported, there were seventeen complications during the treatment stage: in twelve the Kirschner wire was not rustproof and osteitis developed; in seven of these the fracture had been open. There were no deaths. In final results, there were thirty-nine cases of disturbance of function, from various causes, including two pseudarthroses. Functional recovery was complete in 74 per cent of all the cases: 81.8 per cent for upper-arm fractures, 71.8 per cent for forearm fractures, 65 per cent for thigh fractures, and 74 per cent for leg fractures.

The author recommends his method for oblique and spiral shaft fractures, which tend to shift; for simple transverse fractures, which used to be treated by continuous traction or open reduction; and for fractures in which healing has already begun but where the position of reduction remains precarious. *Diafixation* has decreased the cost of treatment, especially by shortening hospitalization, and has led to favorable over-all results in the type of fracture to which it is applicable. It requires skill and experience, as does any method. As experience is being gained, the results are improving.

This book is a thorough presentation of the author's refinements of a method of internal fixation that is useful for certain types of fracture. It is worth reading, or at least scanning for the excellent illustrations, by any surgeon interested in the special problems of fixation of fractures of the long bones. The bibliography contains thirty-five references, mostly to the European literature.

F. W. Rhinelander, M.D.



BONE CYST . . . 4 aspects

Radiograph *(upper left)* of bone cyst of the fibula. The lesion has its characteristic location in the end of the shaft and does not transgress the plate.

Photograph *(upper center)* of external surface of upper end of fibula resected because of the presence of a bone cyst. The contour of the cystic area is expanded, and two healed fracture lines are to be noted.

Photograph *(upper right)* of transected specimen showing the lesion illustrated above, center. The cyst cavity contains considerable organizing blood, which was present because of recent fracture.

Photomicrograph (x 3) *(left)* showing topography of the fibular cyst. From above down, one notes epiphysis, epiphyseal cartilage plate, and cyst wall abutting upon the metaphyseal spongiosa and plate area.

For data on Nonossifying Fibroma, turn page.

For Staff Meetings, Teaching, Research

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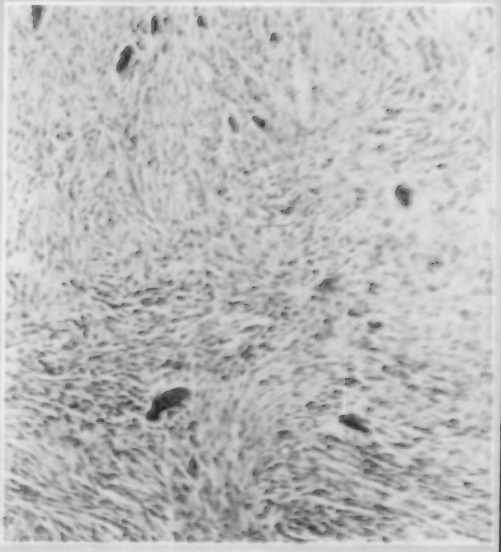
NONOSSIFYING FIBROMA . . .
3 aspects

Radiograph *(upper left)* of a nonossifying fibroma in the shaft of a fibula of a boy of 8 years. The lesional area appears somewhat loculated.

Photograph *(upper right)* of segment of fibula (cut longitudinally) containing the lesion shown in the preceding radiograph.

Photomicrograph (x 15) *(right)* showing the general pattern characteristic of the lesional tissue of nonossifying fibroma. The stromal cells are spindle-shaped and whorled, and intermingled with small numbers of giant cells.



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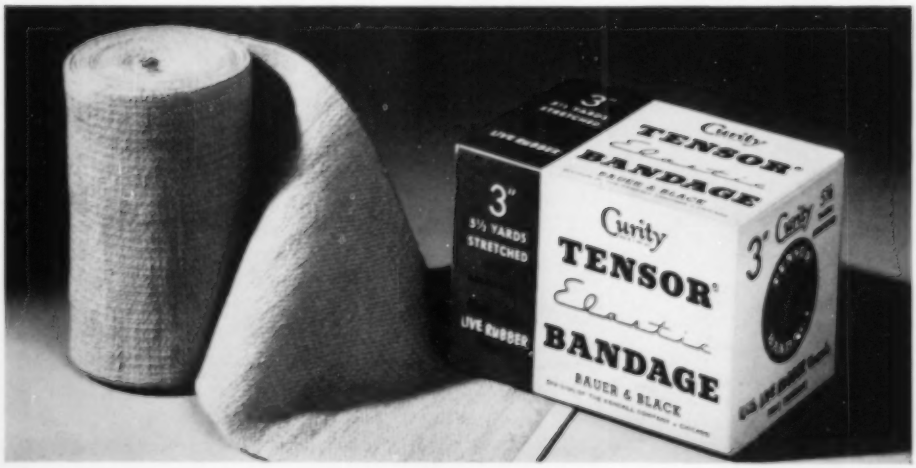

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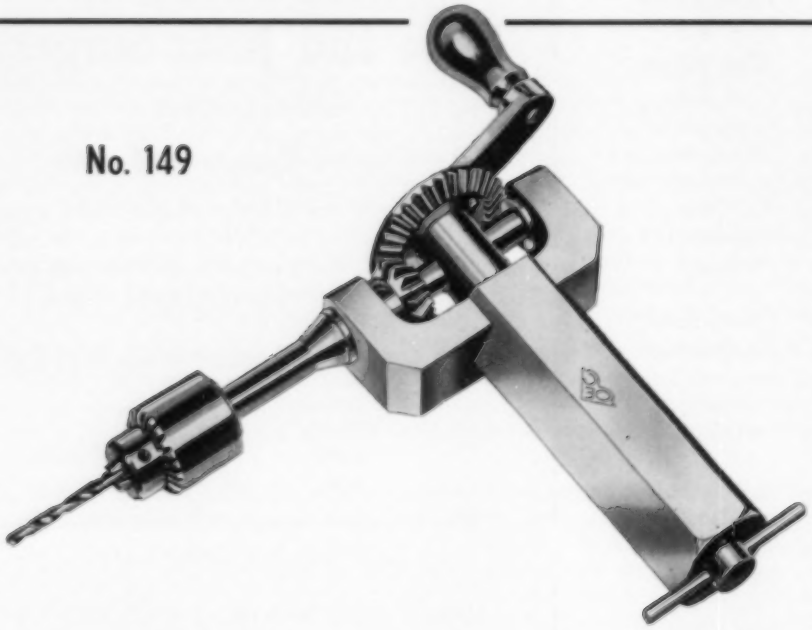

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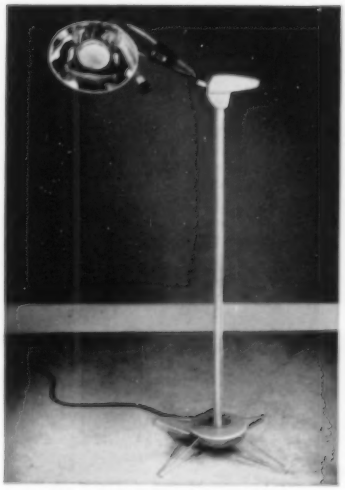

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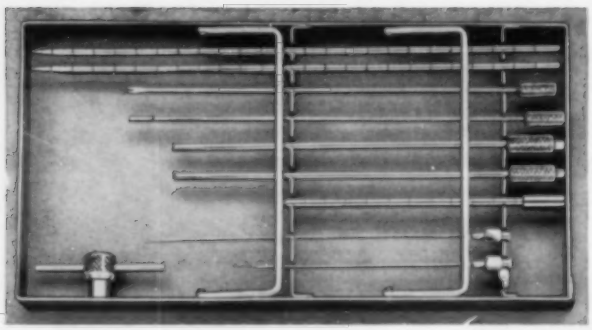

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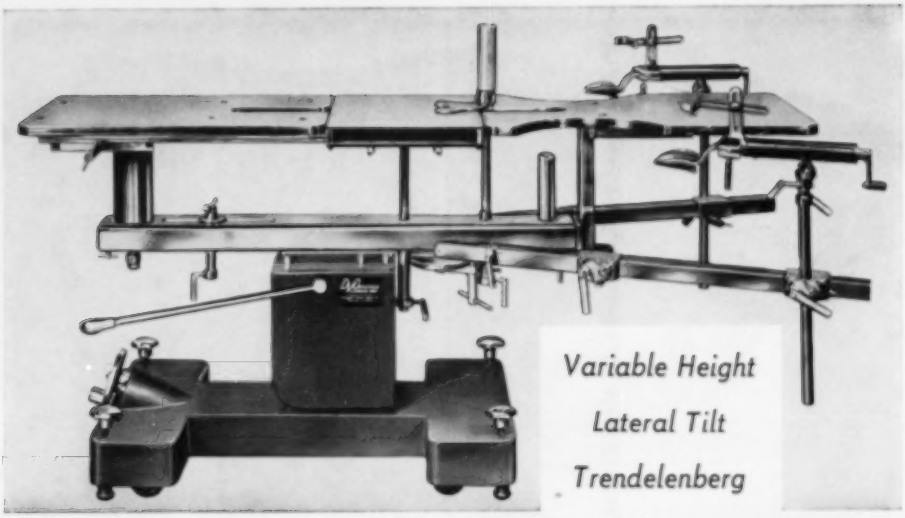

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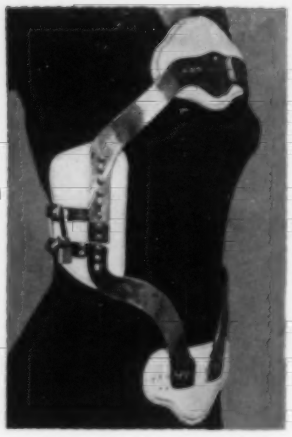

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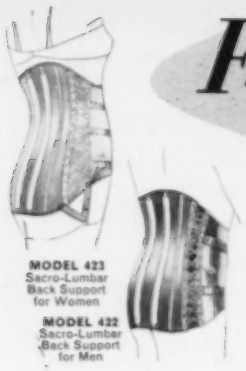

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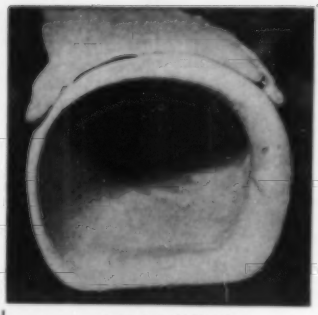

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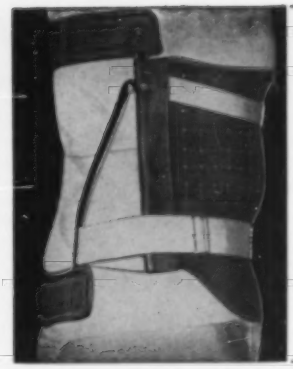

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List of Advertisers

OCTOBER 1958

	PAGE
Aireloom Bedding Company	55
C. H. Alden Shoe Company	33
A.S.R. Corporation, Hospital Division	15
Austenal, Inc.	29, 30, 31, 32
Ayerst Laboratories	13
Bauer & Black, Division of the Kendall Company	8, 51
Bowen & Company, Inc.	17
Bristol Laboratories, Inc.	4, 5
S. H. Camp and Company	14
Carlson Duesing Co., Inc.	52
Chattanooga Pharmacal Company	59
G. W. Chesbrough, Inc.	57
Chesebrough-Pond's Inc., Professional Products Division	22
Gilbert Hyde Chick Company	58
C. & J. Clark Limited	64
Codman & Shurtleff, Inc.	7
Columbia University	62
Connecticut Bandage Mills, Inc.	61
DePuy Manufacturing Company, Inc.	23
Eastman Kodak Company	49, 50
Elgin Exercise Appliance Co.	57
Fillauer Surgical Supplies, Inc.	59
Florida Brace Corporation	60
Freeman Manufacturing Company	62
S. R. Gittens	65
J. E. Hanger, Inc.	24
Herbst Shoe Manufacturing Company	25
Hill Laboratories Company	58
House of Bidwell	66
Johnson & Johnson	48
Kastoff Company	63
Kayser-Roth Hosiery Company, Inc.	26
Ken Standard Corp.	65
Kleistone Rubber Company	58
McNeil Laboratories, Inc.	19, 20, 21, 44, 45
Manuflex Co.	60
M. J. Markell Shoe Company, Inc.	36
Medic Shoe Manufacturers, Inc.	38
Medical Research Specialties	35
Miller Brace Co.	65
Minnesota Orthopedic Services	63
V. Mueller & Co.	56
Orthopedic Equipment Co.	54
Orthopedic Frame Company	28
Orthopedic Pocket Knife	60
J. A. Preston Corp.	64
Price Filler Machine & Mfg. Co.	56
Riker Laboratories, Inc.	34
I. Sabel, Inc.	40
Schering Corporation	47
Chas. A. Schmidt Surgical Instrument Company	37
Simmons Company	18
Smith Kline & French Laboratories	41
Spencer, Incorporated	39
E. R. Squibb & Sons	42
Truform Anatomical Supports	43
The United Limb and Brace Co., Inc.	63
United States Manufacturing Company	46
Wallace Laboratories	16
H. Weniger	62, 64
Westwood Orthopaedic Appliance Co.	61
Wilmot Castle Company	55
Wright Manufacturing Company	6
Wyeth Laboratories	27
Zimmer Manufacturing Company	9, 10, 11, 12

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OCTOBER 1958

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